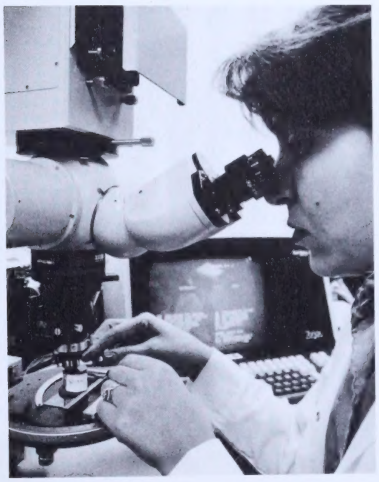
ALBERTA OFFICE OF COAL RESEARCH & TECHNOLOGY

ANNUAL REVIEW 1991/92



Alberta ENERGY
Research and Technology Branch

Cover photo courtesy of Alberta Research Council

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Preamble

The Alberta Office of Coal Research and Technology was established January 20, 1984, by Ministerial Order under the Department of Energy and Natural Resources Act.

The purpose of the Office is to coordinate the Alberta government funding needed to identify, investigate and develop coal-related technologies considered to be commercially important during the next decade.

Its goals are:

- to minimize the environmental impact of coal production, transportation and use in Alberta and elsewhere, with particular emphasis on coal-fired power generation;
- to enhance the competitiveness of Alberta coals in domestic and international markets; and
- to develop new uses for Alberta coals.

Appointed to the Office are J.K. Kleta as Chairman, and Garnet T. Page and Michael A. Ward as Members. T. David Brown represents Energy, Mines and Resources Canada as an observer and participates in project reviews.

Initial government funding for the Office was provided by the Alberta/Canada Energy Resources Research Fund (A/CERRF). This fund was fully depleted in 1991/92. Additional funding is being provided by the Alberta Department of Energy.

Introduction

Chairman's Report

During 1991/92, the Alberta Office of Coal Research and Technology continued to support coal research and technology development through the Alberta Coal Research Program and the Western Canadian Low-Sulphur Coal to Ontario Program. This was the final year that the Alberta Coal Research Program received funding from the Alberta/Canada Energy Resources Research Fund, as this fund is now depleted. Additional funding, however, is being provided by the Alberta Department of Energy.

Most research projects in the two programs managed by the Office were carried out and partly funded by the private sector and/or other governments.

All these investigations were based on the 1983 Alberta Coal Research Strategy, which was revised in 1990 after consultation with the private sector and interested government agencies. This consultation led to research goals for the 1990s that will help develop coal-related technologies which are considered to be commercially important for the period 1995 to 2005. These goals are:

- to minimize the environmental impact of coal production, transportation and use in Alberta and elsewhere, with particular emphasis on coal-fired power generation;
- to enhance the competitiveness of Alberta coals in domestic and international markets; and
- to develop new uses for Alberta coals.

These goals will allow the Office to continue to build on its past activities and experience, and will require an even greater emphasis than before on the environmental aspects of coal production and use.

During 1991/92, projects funded by the Office helped several technologies to advance toward commercial applications. For example, Fording Coal Ltd. and the Alberta Research Council (ARC) are working with other companies to explore the prospects for commercial application of their coal/oil upgrading and agglomeration processes. Other technologies that have been developed nearly to the commercial stage include: the Low NO_x/SO_x Burner of TransAlta Utilities Corporation; the coal/oil co-processing technology of Canadian Energy Developments Inc.; and coal/water and coal/oil slurry technologies that have been supported by the Office in the past.

Current research priorities include:

Environment-Related Technologies:

- Low NO_x/SO_x Burner Demonstration (also related to new uses for Alberta coals);
- CO_2 Use in Enhanced Oil Recovery; and
- Advanced Coal Combustion Science (improved efficiency and reduced emissions of NO_x).

Technologies to Enhance the Competitiveness of Coal:

- Tailing Ponds Reclamation;
- Conversion of Open Pits to Sport Fishery Lakes;
- Coal Preparation Plant Optimization Procedures; and
- Underground Thick-Seam Mining Technologies.

New Uses for Coal Technologies:

- Coal/Oil Upgrading;
- Coal/Oil Co-processing; and
- Carbon Fibre Development.

The Office continued to provide administrative support to the single remaining industry/government technical committee established previously. This committee, The Canadian Gasification Steering Committee, continues to be active and this year supported a major gasification investigation by the Alberta Research Council and CANMET.

The CO_2 R&D Network (CORDNET), which was created last year, acts primarily as an information-sharing body, rather than a typical technical committee. CORDNET was partly responsible for the development of a new project that is examining CO_2 disposal in groundwater aquifers.

The Office continues to encourage collaboration among research and development organizations in Alberta, Canada, and several other countries. In 1991, members of the Office were directly involved in the National Advisory Council on Coal Research (NACCR) which comprises senior executives from the Canadian coal industry, federal and provincial governments and the research community.

NACCR was created to:

- define the requirements for coal research, development and demonstration (R,D&D), according to the needs of industry and governments;
- recommend priorities for a national R,D&D program, and promote the development of the most appropriate technologies for coal production and use; and
- provide guidance for coal R,D&D activities throughout Canada.

Recommendations made by NACCR about the needs of Alberta's coal industry are reflected in the research program of the Office.

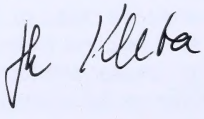
Internationally, the Office is involved in projects with Japan, Germany, and several European countries through the International Energy Agency.

During 1991/92, the Office received 62 requests for research funding, of which 12 new projects were approved for Office contributions. In addition, funding support was continued for nine projects approved previously. Total 1991/92 research funding contributions by the Office were $2.0 million, representing 26 per cent of total research expenditures for approved projects.

The Office members met eight times in 1991/92, and were advised on the technical merits of project proposals by a Coal Research Review and Selection Committee. Members of this committee were D. Macdonald, (Alberta Department of Energy, Chairman), A. Turak (Alberta Department of Energy, Secretary), D. Deshpande (Alberta Power Limited), V. Plitt (University of Alberta), S. Hunter (The Coal Association of Canada) and T. Cyr (AOSTRA).

Day-to-day administration of research projects is provided by staff in the Research and Technology Branch of Alberta Department of Energy. Additional assistance, cooperation and considerable support were received from the coal industry, research institutions and intergovernmental organizations.

The results of many investigations supported by the Office are available to industry and other interested parties through technology transfer publications. These are available from the Office or the Alberta Energy/Forestry, Lands and Wildlife information centres in Calgary and Edmonton.



J.K. Kleta
Chairman

Background

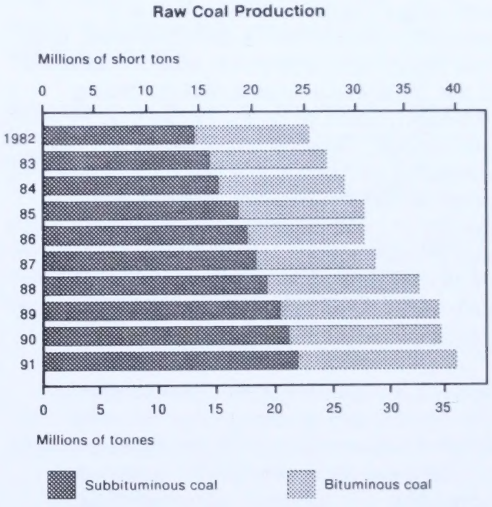
Alberta's coal industry provided an important energy source during early development of the province. It continued to contribute significant economic activity until about 1950 when the coal market collapsed because large amounts of oil became available as a replacement fuel. In the mid-1960s, a resurgence occurred in the export market for metallurgical coal and in the provincial market for thermal coal. By 1974, annual production had risen to 9.5 million tonnes.

Alberta's raw coal production rose steadily after 1975, reaching 35 million tonnes in 1989. In 1991, raw coal production was 37 million tonnes, a five per cent rise over the 1990 level of 35.2 million tonnes.

Today, Alberta is Canada's largest coal-producing and coal-consuming province. Its 12 major coalmines produce three types of coal for three different markets. Approximately two-thirds of total production is subbituminous coal produced from plains mines and used for power generation at mine-mouth, electricity-generating stations.

High-quality, bituminous metallurgical coal is produced from three mountain coalmines for export to the steel industries in Japan, Korea and Brazil. Low-sulphur bituminous thermal coal is produced from two mines in the foothills region of Alberta for export to Ontario, Japan and Korea. Also, five small mines in the plains area of the province supply coal for the local market.

Although the international coal market is still in an oversupply situation, several thermal coal mines in the foothills region have been approved for development when export markets warrant. Income earned by Alberta's coal producers is derived from exports of bituminous coals, and from subbituminous coals used by Alberta utility companies to produce more than 91 per cent of Alberta's electricity. Approximately 2 400 people are directly employed by Alberta's coal producers.



These statistics emphasize the importance and some of the benefits of Alberta's coal industry, but there are other advantages to having a healthy coal industry in the province. For example, coalmines provide a high economic and social return on the affected land. Also, the sale of coal to other countries improves Canada's trade balance, contributes to expansion of the transportation network, and fosters growth in the provincial construction industry during periods of expansion. Other direct benefits include financial contributions to all levels of government, and the purchase of goods and services within Alberta.

It is expected that Alberta's coal industry will continue to supply the low-sulphur fuel that makes electricity available to all Albertans at little economic or environmental cost. In addition, it will encourage the growth of secondary industries, provide a reliable and economic energy source for recovery of the province's heavy oils and bitumen, and make other significant contributions to the province's economic base.

To optimize these benefits, however, coal-exporting companies must continue to capitalize on economic events overseas. This was made more difficult this year by upheaval in the Japanese economy and continuing downward pressure on the prices paid for Alberta coal. Although this situation is somewhat hampered by a rising Canadian dollar relative to several currencies, some of the rise in raw coal production this year was in response to improved demand from offshore buyers, while the remainder came from the operators of Alberta's thermal electric plants.

Today's market conditions make it essential that Alberta coal producers use the most efficient and economical technologies available in coal exploration, production, preparation, upgrading, transportation and marketing. Increasingly, overseas customers are demanding coal and coal products that exhibit specific qualities and behaviour. This means that coal producers must know more about the combustion characteristics of their products. They must also be involved in the development of new technologies such as agglomeration, coal-water fuels, and other upgrading processes that will produce coal products tailored to market requirements.

The Alberta coal industry's response to these difficulties and challenges is expressed in the Alberta Coal Research Strategy, published in November 1983 and revised in 1990. This document was the result of extensive discussions among individual companies and the provincial government. Following the initial round of discussions in 1983, the Alberta Office of Coal Research and Technology was established in 1984. Subsequent industry proposals that were submitted to the Office resulted in research and development projects funded jointly with the Alberta government.

Other research projects funded by the Office have been carried out by the Alberta Research Council and the former Coal Mining Research Company.

Another important function provided by the Alberta Office of Coal Research and Technology is the coordination of coal research and development activities within Alberta, as well as between Alberta and national and international agencies.

This activity has led to better integration among the various coal research groups in Alberta. Also, it has resulted in a stronger focus on the needs of industry, and has produced international contacts and greater international cooperation.

The Office has directly influenced research and development activities within Alberta by funding projects jointly with the following: individual coal-producing companies or groups of companies, other government agencies, universities, private research organizations, consultants, utilities, equipment suppliers and agencies in other countries.

The Office is both influencing and benefitting from coal research and development elsewhere by participating on various national and international committees, including the International Energy Agency's Working Party for Fossil Fuels, and the Canada/Japan Coal Conversion Research and Development Committee.

Coal Research Strategy

Research Rationale

Consistent with the views of the Government of Alberta, the Alberta Office of Coal Research and Technology believes the private sector should take the lead in identifying and managing appropriate research and development programs, as well as implementing and commercializing the results. The role of the Office and other government agencies such as the Alberta Research Council, along with universities and research organizations, is to support the private sector as necessary to achieve the desired technical results most efficiently.

While there is a recognized need for longer-term research and development, as well as basic research to facilitate a better understanding of coal properties and uses, the critical time for commercial expansion and economic development of the province's coal resources will be from 1995 to 2005. During this time, growth in thermal coal use throughout the world is probable, but Alberta's share of the market will be influenced by increased competition from other coal exporters. The extent to which this expansion of thermal coal use can be realized, however, will depend on the prices of other energy supplies, such as natural gas and oil, and the relative social and environmental acceptance of coal versus other fuels or nuclear power.

Towards this end, in 1984 the Alberta Office of Coal Research and Technology identified initial funding through the Alberta/Canada Energy Resources Research Fund of approximately $20 million in support of research, development or demonstration projects. It was anticipated that similar funding would be forthcoming from the private sector. Thus far, contributions from industry have exceeded $36 million.

A portion of the funding now available from the Alberta Department of Energy is being used for longer-term or fundamental research directed toward innovative technologies related to production and use of Alberta coals.

Alberta must collaborate closely with research groups elsewhere to ensure that maximum benefit is derived from the total international coal research and development effort, and to define its intermediate- and long-term plans within this context.

In pursuing its objectives, the Alberta Office of Coal Research and Technology works closely with The Coal Association of Canada, the Alberta coal industry and coal research agencies to establish research and development priorities. In addition, the Office maintains contacts world-wide with researchers who are engaged in coal-related studies.

Administrative Framework

The Alberta Office of Coal Research and Technology does not have in-house facilities to carry out research. Rather, its primary role is to provide funding for approved coal research projects. Therefore, procedures have been established to ensure sound management and financial control of approved projects. For each project, specific agreements are signed that define the terms and conditions under which the work will be conducted and funded. These agreements also define the respective rights to new project technology ownership and use.

After proposals have received thorough consideration, those falling within the interests of the Office are discussed in detail with the applicant, and are often referred in confidence to one or more experts for detailed technical review.

An Alberta government interdepartmental group has been established to review and comment on the implications of the proposed research on their areas of responsibility. This group includes representatives from the Energy Resources Conservation Board and the departments of Forestry, Lands and Wildlife, Economic Development and Trade, Environment, and Occupational Health and Safety.

Approval of research proposals by the Alberta Office of Coal Research and Technology takes into consideration the results of these reviews, relative funding contributions and the likelihood that proposed research will contribute to achieving the goals of the Alberta Coal Research Strategic Plan. Those projects funded by the Alberta/Canada Energy Resources Research Fund were submitted subsequently to the A/CERRF Committee for approval.

Research Priorities

Since the Alberta Coal Research Strategy was prepared in 1983, several important events have occurred that could significantly affect Alberta coal producers, particularly those depending on export sales.

For example, Ontario Hydro is considering the use of more low-sulphur western Canadian coals to help meet provincial acid gas emission guidelines and establish a reliable domestic coal supply. This has resulted in a commitment by both industry and government to reduce the delivered cost of western Canadian coal in Ontario.

In Alberta, emphasis is being placed on expanding opportunities to use coal in place of natural gas to generate steam for enhanced oil recovery operations.

World-wide, the development of new coal-use technologies is generating demand for certain types of internationally traded thermal coals. Suppliers are now aware they should be providing thermal coals tailored to these new systems. Success in these markets will depend on having a better understanding of the performance characteristics of coal products under different operating conditions. Coal gasification developments are of particular interest to the Office and Alberta coal producers.

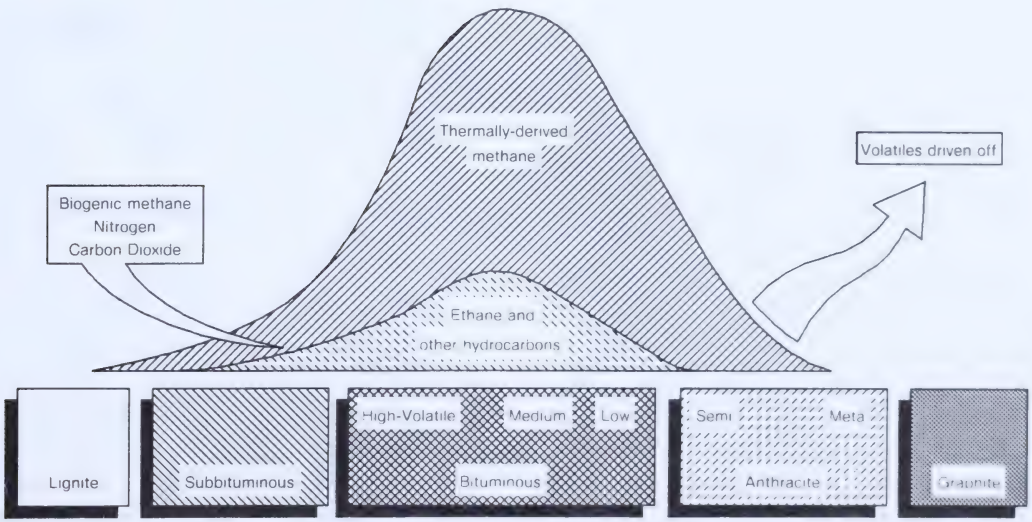
These changes have been influential in bringing about some modifications to the research priorities of the Alberta Office of Coal Research and Technology.

Currently, those priorities are as follows:

- to develop and apply clean-coal technologies that are cost efficient and reduce the production of harmful atmospheric emissions. (While progress has been made in reducing SO_x and NO_x, emphasis is now needed on methods for reducing, removing or capturing CO_2);
- where there is a clear benefit to the Alberta economy, to develop and apply coal transportation technologies that will have a reduced effect on the environment; and
- to develop technologies that will improve coal production, quality and mining and result in minimal disturbances of land and water bodies. Again, this activity must be economically beneficial to Alberta.

During 1991/92, the objective was to proceed with these priorities while considering the recommendations of the National Advisory Council on Coal Research.

Gas Generation In Coal



Research and Technology Programs

During 1991/92, the projects administered by the Alberta Office of Coal Research and Technology were supported by three sources of funding: Alberta/Canada Energy Resources Research Fund, Alberta Department of Energy, and governments participating in the Western Canadian Low-Sulphur Coal to Ontario Program.

Projects under way in each of these programs are described in the following section.

Department- and/or A/CERRF-Funded Projects

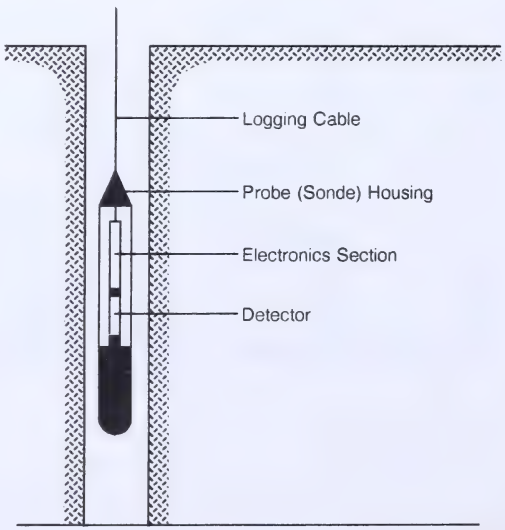
Resource Evaluation

In applying technology to the challenge of making Alberta coals more competitive in various markets, a significant opportunity is created by the need to match coal quality to coal uses, and to reduce costs related to coal exploration and mine planning.

Thus, researchers sponsored by the Office have attempted to correlate seismic, direct current electric, magnetic and electromagnetic data from above-ground surveys of prospective coalfields with laboratory analyses of drilled cores. In this way, they have begun to develop less-expensive methods for locating coal and evaluating its characteristics. More recently, a study was undertaken of the coal-bed methane resource in Alberta. All indications suggest that this resource is sizeable and worth investigating in detail in certain areas of the province.

Since 1985, the Alberta Office of Coal Research and Technology has helped fund 14 coal resource evaluation projects, 13 of which were completed and described previously. The remaining project was completed this year and is described in the following section.

The completed projects are described in detail in the technology transfer booklets *Geotechnical Studies of Overburden and Coal at Alberta Coal Mines; Some Studies of Alberta's Coal Geology*; and *Development of Geophysical Methods for Coal Exploration in Alberta*. Copies are available at Alberta Energy/Forestry, Lands and Wildlife information centres in Calgary and Edmonton.



Coal-Bed Methane: An Alberta Opportunity

ALBERTA RESEARCH COUNCIL, EDMONTON

In recent years, considerable research effort has been expended in Alberta to study methods for gasifying coal. While this work may lead to the construction in Alberta of a commercial-scale gasification plant, a parallel approach is to extract methane from coal beds as is done now in the U.S.A. Coal-Bed Methane (CBM), as it is called, is a natural, low-pressure and low-temperature *in situ* gasification process that produces methane without the need for coalmining, subsequent gasification and effluent cleanup. Based on U.S. experience, it is assumed that CBM resources are widespread in Alberta, but it is not certain whether CBM can be recovered economically.

The Alberta portion of the Western Canadian Sedimentary Basin contains over 7×10^{12} tonnes of coals that range in rank from lignite to semi-anthracite. These coals are distributed throughout the mountains, foothills and plains regions, and range from Jurassic to Tertiary in age. Most of the coal in the plains region is subbituminous, while bituminous coals are common in the foothills and mountains. Promising geologic settings for coal-bed methane recovery are found in all three regions.

The first test of Alberta coals for methane commenced in 1974. Plains coals to a depth of approximately 400 m were explored extensively and evaluated by the Alberta Geological Survey in the early-1980s. The deep coal resources have received considerably less attention, despite being penetrated by thousands of petroleum exploration and production wells.

Meanwhile, the Alberta petroleum industry has shown renewed interest in CBM, and companies have begun to test samples and acquire land positions.

Thus, a CBM project was begun by the Alberta Geological Survey during the summer of 1990. The work was supported by the Office, CANMET and 14 oil and gas companies. The project involved revising and improving the resource estimates of coal in non-traditional mining areas. A CBM database was established that should provide a better measure of this resource. The database draws upon existing geological information, and was augmented with new data derived from coal chip samples. The resource evaluation defined the stratigraphic and structural framework of the coals throughout the province. This was accomplished by producing an extensive suite of cross-sections and maps. Regional trends in subsurface coal rank were defined for the entire province for the first time. This was done by collecting hundreds of vitrinite reflectance measurements. The database includes information on the distribution, thickness, structure and rank of CBM-prone coals in Alberta.

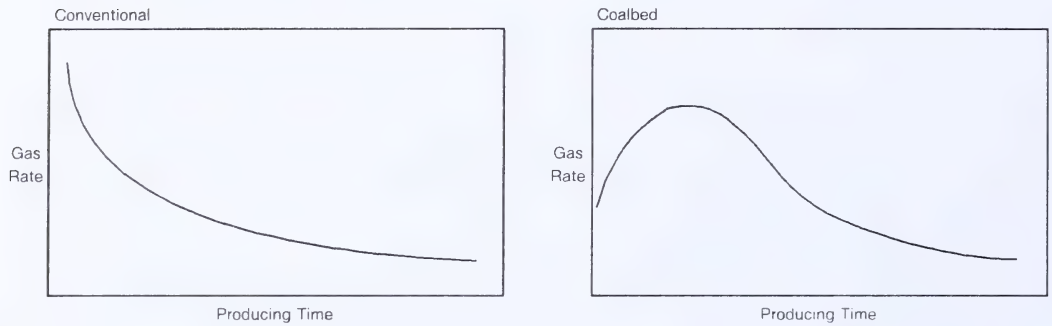
It was concluded that the Ardley zone in the plains region, which has the most extensive coal seams in terms of area, also has the greatest potential for coal-bed methane, but it is at depth toward the disturbed belt. The Drumheller coal zone also shows some promise. Although it is not as extensive as the Ardley, and most coals are too shallow to be considered prime candidates for coal-bed methane, Drumheller coals should not be ignored. The Upper Mannville coals are regarded as primary targets for coal-bed exploration, particularly those located near Red Deer.

The foothills contain several coal zones having potential for coal-bed methane. The best in the Coalspur coal zone appears to be in the Cadomin and Nordegg areas. Also, the Gates coals near the Narraway River, Grande Cache, Cadomin and Nordegg should be promising. In the mountains, the best prospects are believed to be in the Kootenay Formation near the British Columbia border.

Publication

Rottenfusser, B., W. Langenberg, G. Mandryk, R. Richardson, B. Fildes, J. Olic, S. Stewart, R. Eccles, C. Evans, M. Spelrem, B. Sprecher, M. Brulotte, T. Gentzis, D. Wynne and L.P. Yuan. 1991. Regional Evaluation of the Coal Bed Methane Potential in the Plains and Foothills of Alberta, Stratigraphy and Rank Study. Alberta Geological Survey.

Gas Recovery



Preparation and Upgrading

In a world coal market characterized by considerable competition, depressed prices and emerging coal-use technologies, consumers have become more demanding about product consistency in terms of combustion characteristics, ash production and the formation of air pollutants. To satisfy these demands, techniques for removing non-combustible mineral matter and moisture in coals are constantly being improved. This not only allows producers to supply higher-quality coals, but also reduces the cost of shipping non-combustible substances having no economic value.

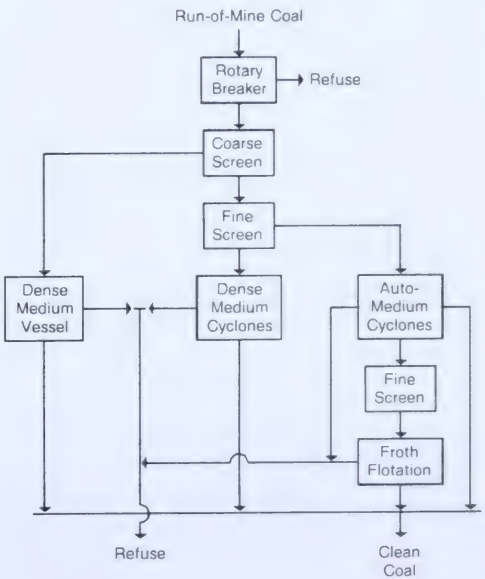
Although washing continues to be the most common coal preparation method, it generates substantial quantities of tailings formed from the clays and fines associated with Alberta coals. These tailings represent lost product and require large storage lagoons as an environmental protection measure. Therefore, alternatives to current washing techniques are needed.

As modern fuel standards have become more stringent in response to the availability of new or improved combustion technologies, coal researchers world-wide have begun to develop methods to upgrade coal into products from which most of the nitrogen and sulphur have been removed, or which have been energy-enhanced.

These types of investigations are being pursued in Alberta, particularly those aimed at upgrading bituminous and subbituminous coals to enhance their energy content and combustion performance characteristics, and to recover more fines in the form of economically valuable products.

Thirty-four coal preparation and upgrading projects have been supported by the Office. The following section contains descriptions of two that were active in 1991/92. One additional research project is described in the section dealing with the Western Canadian Low-Sulphur Coal to Ontario Program.

The results of some coal preparation and upgrading studies were reported in the technology transfer publications, *Coal Preparation Research in Alberta; Studies of Fine Coal Cleaning and Upgrading Processes for Alberta Coals*; and *Recent Studies of Coal Mining, Cleaning and Upgrading*. All three publications are available from Alberta Energy/Forestry, Lands and Wildlife information centres in Calgary and Edmonton.



Electrocoagulation[1]

LUSCAR STERCO (1977) LTD., EDSON

It has been suggested that improving the efficiency of western Canadian coal preparation plants depends on finding a successful process for separating clay from coal fines. Normally, the clay and shale particles that are suspended in process water after coals have been washed are removed in mechanical clarifiers to which chemical coagulants have been added. These coagulants are expensive, however, and process water quality is highly variable and tends to deteriorate with time. This leads to larger amounts of chemicals and rising costs.

An alternative is to use a process called electrocoagulation in which an electric current is passed through a suspension or emulsion, causing a consolidation of the dispersed phase, followed by settling of solid matter. During the process, ions from the electrodes (aluminum, for example) are dispersed in solution. In a trial at Luscar Sterco's Coal Valley mine, the process performed well, but it could not compensate for changes in clay chemistry.

Subsequently, a project was initiated in 1988/89 that involved bench-scale electrocoagulation testing by CANMET at the Coal Research Centre, Devon. The experimental work conducted in the first phase of this project determined the optimum operating conditions for electrocoagulation technology in this application. Initial results indicated that the technology has the potential to be economic, as well as technically effective. It was also determined that the effect of the technology can be extended by treating a relatively clean stream of water before adding it to the contaminated stream. The results indicated that a residual reaction occurred.

Thus, the electrocoagulation technology successfully precipitated particulates over a wide range of conditions, making it attractive for the treatment of high-ash fines and clays associated with Alberta thermal coals.

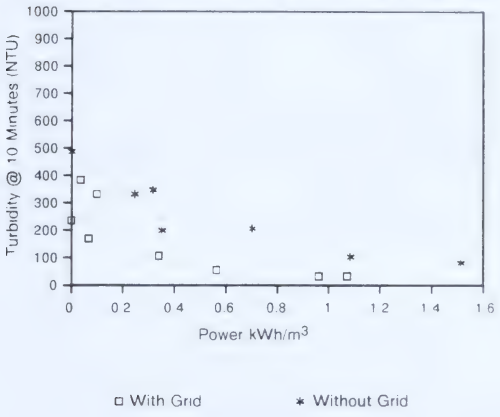
The next step in the project was to obtain an accurate measure of the process economics. Thus, CANMET built a pilot-scale electrocoagulation cell to provide more process control and testing of process variables. Allowance was made for a larger surface area on the electrodes, variable gaps between the electrodes, variable electrode materials and various flow rates.

Initial tests using the pilot-scale cell and kaolinite/bentonite clay mixtures showed that flow conditions in the test cell had a significant effect on the electrical power consumption, and power use might be reduced by a factor of three. When a thickener feed from the Coal Valley mine was tested, similar reductions in power consumption were observed. The settling rate for solids, however, was too slow and did not meet the requirements of Luscar Sterco. An increase in the quantity of added chemicals caused quicker settling, but also produced less clear supernatant liquid and incurred extra costs. Also, the use of additional chemicals made the electrocoagulation process virtually identical to a conventional flocculation system, except the electric current replaced the normal use of acids. Ultimately, the overall costs for aluminum electrodes, electricity and flocculating agents were regarded by Luscar Sterco as too expensive. The total costs were up to three times greater than the upper limit expected by the company.

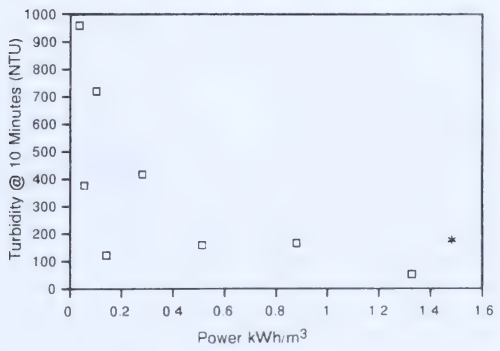
Consequently, the experiment was terminated, but the results did indicate that electrocoagulation may be economic in applications such as municipal water treatment and the treatment of waste streams that contain toxic chemicals.

[1]Funding for this project was provided by Luscar Sterco (1977) Ltd., CANMET and the Office.

Effect of turbulence-promoting grid: flocculent added



Effect of turbulence-promoting grid: no flocculent added



Publications

Donini, J.C., D.K. Garand, T.A. Hassan, K.L. Kar and S.S. Thind. 1991. Electrocoagulation Project - Pilot Scale Testwork. Prepared by CANMET Coal Research Laboratories for Luscar Sterco (1977) Ltd.

Donini, J.C., R.G. Frenette, K.L. Kasperski and S. Kelebek. 1989. Electrocoagulation - Final Report. Prepared by CANMET Coal Research Laboratories on behalf of Luscar Sterco (1977) Ltd.

Coal/Oil Upgrader

FORDING COAL LIMITED (CALGARY) AND OTHER PARTICIPANTS[1]

Based on the promising results thus far from the Agflotherm Process developed by the Alberta Research Council/EPRI consortium, Fording Coal Limited and PanCanadian Petroleum Limited propose to build a commercial-scale coal upgrading plant. This facility would use a specific heavy oil/subbituminous coal combination to produce an agglomerated, low-ash, low-moisture coal product, and it would simultaneously recover upgraded oil having an API gravity of 19°-25°. Thus, the ash and moisture content of the coal product should be approximately 30 to 50 per cent lower than for the parent coal, and the recovered oil should easily be hydrotreated to synthetic crude oil specifications.

Thus far, laboratory studies were carried out at the Alberta Research Council to produce agglomerates and then they were dewatered and de-oiled. While the production of agglomerates from Dodds subbituminous coal and Elk Point heavy oil was routine, the agglomerates could not be mechanically dewatered to the desired level of 20 per cent, and a single pass through a rotary kiln was not satisfactory in de-oiling the agglomerates.

Consequently, Raymond Mineral Dressing Consultants of Calgary reviewed the laboratory results and proposed a commercial-scale, multi-stage equipment train that should be capable of reducing the moisture to the desired level and allow recovery of both the residual oil and essentially oil-free agglomerates.

At year-end, it was recommended that a vendor-testing program be initiated. This would allow various manufacturers to try dewatering or de-oiling the agglomerates in their equipment.

[1]In addition to Fording Coal Limited and the Office, PanCanadian Petroleum Limited and CANMET provided funding for this project

Combustion

Some emerging coal combustion technologies achieve optimum performance from coals having narrowly specified properties. Consequently, coal producers who wish to sell coal to the users of these technologies must be prepared to provide detailed information about the combustion characteristics of their coals. This also implies that coal producers should know how a coal will likely perform in combustion equipment even before it is removed from the ground. Therefore, developments in combustion technology have a direct bearing on resource evaluation and coalmining and upgrading. Furthermore, advances in the science of coal combustion make it necessary to test coals for properties other than those revealed by ultimate and proximate analyses. This means new or improved laboratory-scale combustion testing methods must be developed that not only simulate coal burning in thermal plants but, ideally, can minimize the need for the expensive, full-scale combustion tests used in the past.

Another important function of coal combustion research is to encourage coal producers, coal users and manufacturers of coal-burning equipment to become jointly involved in projects. This can lead to knowledge sharing and the enhancement of technology development in ways that benefit all parties.

With these issues in mind, the Office has supported 21 coal combustion research projects, four of which were active in 1991/92 and are described in the following section.

Also, some completed studies are described in the following technology transfer publications: *Some Combustion Studies of Alberta Coals*; and *Some Recent Studies of Coal Combustion and Gasification.* Both are available from Alberta Energy/Forestry, Lands and Wildlife information centres.

International Energy Agency Coal Combustion Science - Program Extension

NETHERLANDS ENERGY RESEARCH FOUNDATION ECN, PETTEN

Annex II of the International Energy Agency Combustion Science Research Program involves fundamental studies and a series of investigations using semi-industrial scale coal burners to advance the science of pulverized coal combustion and minimize adverse environmental effects. Facilities of the International Flame Research Foundation (IFRF) at IJmuiden, The Netherlands, are being used, and the Office has provided partial funding since 1985.

The principal objective is to provide information that can be used to design burners capable of using a wide range of coals and producing flames having acceptable combustion characteristics, while generating few atmospheric pollutants.

The Annex II studies are funded jointly by Canada, The Netherlands, the Federal Republic of Germany and Great Britain. The Canadian contribution has been divided among CANMET, the Canadian Electrical Association, and the Alberta Office of Coal Research and Technology.

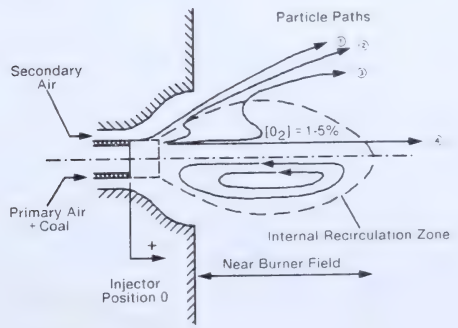
The primary objective of the research under way this year was to gain a better understanding of the influence of coal characteristics and burner design on emission levels, using the air-staging and fuel-staging processes developed at IFRF.

Past work included studies of the effects of coal blending on the performance of the Aerodynamically Air-Staged Burner (AASB), effects of mixing on NO_x reduction, coal combustion characterization, modelling the in-flame data generated in scale-up trials, and performing preliminary studies on the modelling of NO_x formation in coal flames. As well, new laser-based flow visualization techniques were developed to study the interaction between coal particles and swirling flows.

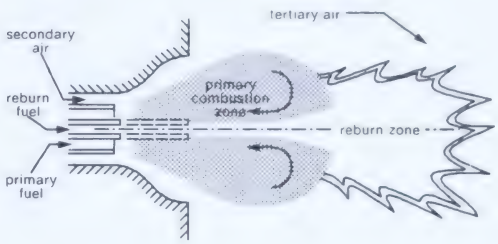
In 1991/92, work began on several topics. Included were: scale-up of the AASB to 12 MW; flame-flame interactions; and fuel stage combustion using an Internally Fuel-Staged Burner and tangentially fired boilers. The study of tangentially fired boilers is of particular interest to utility companies in Alberta. Also under way this year were investigations of coal-combustion characterization, and the combustion of pulverized coal using turbine exhaust gas as the air supply for a coal flame. Numerical modelling continued for a model of NO_x formation.

As in previous work, Alberta coals were included in semi-industrial scale testing of the internally fuel-staged burner and those involving turbine exhaust gas combustion.

Schematic of the Aerodynamically Air Staged Burner (AASB)



Schematic of the Internally Fuel Staged Burner (IFSB)



Publications

Dugué, J. and M.P. Abbott. 1989. LDA Measurement in Semi-industrial Gas and Coal Flames. Report on the AMT 1 Investigation. IFRF Document F 072/a/18.

Dugué, J., P. Ereaut, H. Horsman and A. Shand. 1990a. Laser Sheet Visualization in Cold Flows, Gas and Coal Flames in the IFRF Furnace No. 2. Results of the AMT 2 Investigations. IFRF Document F 072/y/19.

Dugué, J., P. Ereaut, H. Horsman and A. Shand. 1990b. Laser Sheet Visualization in Cold Flows and 2.5 MW Gas and Coal Flames. Report on the AMT 3 Investigation. IFRF Document F 072/y/20.

Knill, K.J. 1991. Fuel Staging and Its Implementation in a Novel Internally Staged Burner. PhD Thesis. Technische Universiteit, Delft. International Flame Research Foundation.

Knill, K.J., T.F.J. Maalman, M.E. Morgan and T. Nel. 1990. Characterization of the Combustion Behaviour of Bituminous Coals. Report on the CC 6 Investigation. IFRF Document F 088/y/12.

Nakamura, T., J.P. Smart, W.L. van de Kamp and M.E. Morgan. 1990. Evaluation of the Behaviour of Blends in an Aerodynamically Air Staged Burner. Report on the AP 20 Investigation. IFRF Document F 037/y/22.

Nakamura, T., W.L. van de Kamp and M.E. Morgan. 1990. Evaluation of the Behaviour of Blends in an Air Staged Burner. Report on the AP 20 Investigation. IFRF Document F 037/y/23.

Peters, A.A.F. and R. Weber. (n.d.) The Development of a NO_x Postprocessor - A First Approach. Report on the MMF4-1 Investigation. IFRF Document F 036/y/17.

Sayre, A.N., K.J. Knill and J.P. Smart. (n.d.) Coal Characterization Requirements for Modelling Pulverized Coal Flames. Report on the CC7 Investigation. IFRF Document F 088/y/13.

Smart, J.P. and D.J. Morgan. (n.d.) The Comparison Between Constant Velocity and Constant Residence Time Scaling of the Aerodynamically Air Staged Burner. Report on the AP 22 Investigations. IFRF Document F 037/y/28.

Smart, J.P., W.L. van de Kamp and M.E. Morgan. (n.d.) The Effect of Scale on the Performance of the Aerodynamically Air Staged Burner. IFRF Document F 037/y/19.

Visser, B.M. 1991. Mathematical Modelling of Swirling Pulverized Coal Flames. PhD Thesis. Technische Universiteit, Delft.

Visser, B.M. and R. Weber. 1990. Predictions of Near Burner Zone Properties of Six Swirling Pulverized Coal Flames. Report on the MMF 3 Investigation. IFRF Document F 036/y/14.

Visser, B.M. (n.d.) Tangentially Coal Fired Boilers - A Review. Results of the TFB1 Investigations. IFRF Document G 013/y/4.

Technology Transfer of IEA Coal Combustion Sciences Research

ALBERTA RESEARCH COUNCIL, DEVON

The services of a combustion engineer from the Alberta Research Council (ARC) were provided to the Office to oversee research activities under the International Energy Agency (IEA) Annex II project. He also represents the Office during meetings of the Canadian Technical Committee and the IEA Executive Committee for this Annex.

The following activities were under way this year:

- transferring the results of IEA combustion studies to Alberta companies through seminars at industry sites;
- acting as Alberta's technical representative to the IEA Annex II Coal Combustion Program;
- helping organize shipments of Alberta coal to the International Flame Research Foundation (IFRF); and
- providing miscellaneous technical support to the Office on matters relating to coal combustion and gasification.

Already, the Alberta Research Council has transferred furnace-probe technology that was developed at IFRF, and this allowed ARC to provide some field-testing services for the LNS Burner Steam Generator Demonstration project (described later).

The thrust of the technology transfer aspect of this project is toward the development of low-NO_x combustion technologies, which are suitable for utility applications and non-utility, industrial combustors.

All the funding for this project was provided by the Alberta Office of Coal Research and Technology.

Publications

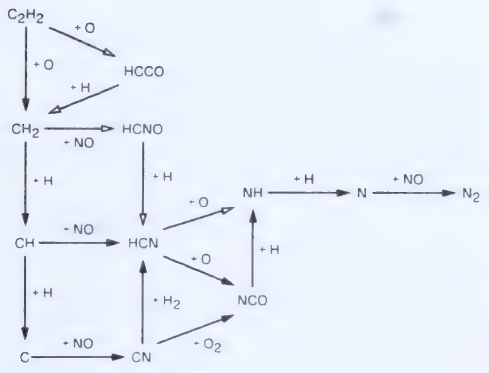
Chambers, A.K. 1992. Technology Transfer of IEA Annex II Coal Combustion Science Research - Fiscal Year 1991/92.

Chambers, A.K. 1991. Coal Utilization Program Planning - Fiscal Year 1990/91. Alberta Research Council.

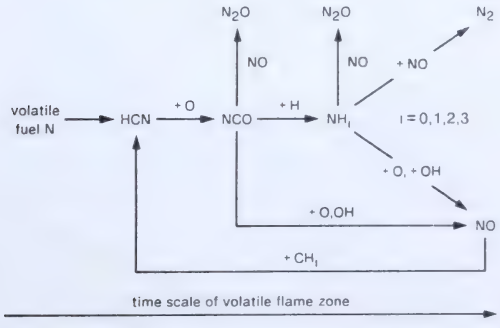
Chambers, A.K. 1990. Coal Utilization Program Planning - Fiscal Year 1989/90. Alberta Research Council.

Chambers, A.K. 1989. Coal Utilization Program Planning. Alberta Research Council.

Model for NO_x reduction by fuel staging



NO_x formation mechanism from volatile fuel-N in coal flames



Ash Properties of Alberta Coals

ALBERTA RESEARCH COUNCIL, DEVON

Approximately 60 to 80 per cent of the coal ash produced by conventional coal-fired power plants is recovered as flyash. Assuming it has certain desirable properties, this flyash might be used as a cement additive, thereby avoiding disposal in a landfill. Since limestone injection into coal-fired furnaces is currently being studied as a method for reducing sulphur oxide emissions from power plants, this project was initiated to determine whether limestone injection would also help produce flyash having desirable cementatious properties.

Flyash samples from both Highvale and Forestburg coals were produced with a 3 kg/h combustor at the Alberta Research Council. Various limestone injection rates and injection locations were used. The produced samples of flyash, and flyash samples from the Sundance and Battle River power plants, were provided to Dr. R. Joshi at the University of Calgary for assessment of their cementatious properties.

These tests included:

- optimum moisture content and maximum dry density;
- scanning electron microscope (SEM) and X-ray studies to determine the morphology (structure) and mineralogy;
- preparation and curing of samples for compressive strength testing at 1, 7 and 14 days to study cementing properties; and
- pozzolanic activity index tests that indicate the suitability of ashes for making cement.

The results of this testing showed that the ashes resulting from limestone addition had better cementatious properties than did those made from raw coal, and the modified ashes could be used as a replacement for cement in concrete. Also, the X-ray and SEM data showed that the modified ashes were structurally different from the unmodified ashes.

It was concluded that the ashes produced on the 3 kg/h combustor were representative of those obtained from the two power plants. Also, the laboratory-produced ashes, modified by the injection of limestone at a rate of 1 to 4 per cent of the coal feed, had the best cementatious properties. It was recommended that additional work at a larger scale be undertaken, and these tests should also determine the optimum location for, and quantity of, limestone injection.

All the funding for this project was provided by the Alberta Office of Coal Research and Technology.

Publications

Chambers. A.K., R. Joshi, R. Zacharkiw and D. Ungarian. 1991. Effect of Calcium Injection on the Cementatious Properties of Flyash. Alberta Research Council/The University of Alberta.

Chambers, A.K., M. Malychuk and R. Zacharkiw. 1990. Ash Properties of Alberta Coals. Alberta Research Council.

Impact of Quality on the Utilization Potential of Alberta Coals and Its Effect on the Environment

ALBERTA RESEARCH COUNCIL, DEVON

Although the contributions that coal makes to atmospheric sulphur oxides, nitrogen oxides and carbon dioxide are the subject of considerable research, a study was begun this year to examine the effects on the environment of virtually every chemical element released from coal. Major, minor and trace elements will be studied, with particular emphasis on their fate when coal is burned. This includes examining the elemental composition of ash residues.

Most of the work will be carried out at the Alberta Research Council, but three agencies[1] will be providing expertise, and external funding is being provided by TransAlta Utilities Corporation and the Office.

In Phase I, which began in the last quarter of 1991, the elemental composition of Alberta subbituminous coals and coal ashes is being studied, with particular emphasis on the organic-inorganic affinities of elements.

At year-end, 120 samples from coal seams had been obtained and most had been analysed.

[1]Funding in kind is being provided by the University of Western Ontario, Alberta Geological Survey and the Geological Survey of Canada. TransAlta Utilities Corporation and the Alberta Office of Coal Research and Technology are providing additional funding.

Liquefaction/Co-processing

During the next 30 years, production of conventional crude oil from Alberta's established oil fields is expected to decline well below current levels. The rate of decline will depend on a number of factors, such as world oil prices and demand, but eventually it will become necessary to produce more synthetic crude oil from Alberta's oil sands, heavy oil and coal.

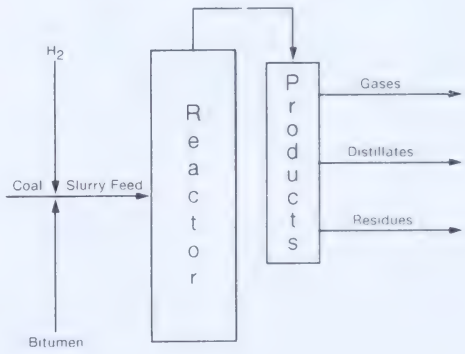
Although the economics of producing oil in this manner are unattractive as long as oil prices are depressed, abundant quantities of raw materials are readily available for extraction whenever the economics become more favourable. For instance, Alberta's proven reserves of subbituminous coals could supply enough synthetic crude oil to satisfy domestic consumption for at least the next century, assuming a suitable and economic liquefaction process can be developed to convert coal to petroleum substitutes.

One conversion concept that is showing some promise, and has been studied extensively in Alberta, involves co-processing of coal and heavy oil or bitumen. This process not only provides a method for producing synthetic crude oil from coal, but may also prove to be useful in upgrading heavy oil. This and other potential liquefaction processes are under development; some may involve less severe reaction conditions than used elsewhere. Also, methods for analysing the quality of liquefaction products are actively being investigated in Alberta; some recent work is pointing toward the possible manufacture of carbon fibre and other chemicals from coal liquefaction products.

The Office has supported 32 coal liquefaction research projects, some of which were multi-year, major efforts. Seven projects, active this past year, are described in the following section.

The Office has published three technology transfer booklets on coal liquefaction: *Co-processing Studies of Alberta Subbituminous Coals; Methods for Producing Liquid Hydrocarbons from Coal*; and *Methods for Producing and Upgrading Liquid Hydrocarbons from Coal*. All are available from Alberta Energy/Forestry, Lands and Wildlife information centres in Calgary and Edmonton.

Generalized Co-processing Schematic



Combined Processing of Coal, Heavy Oil and Natural Gas

UNIVERSITY OF ALBERTA (M.R. GRAY), EDMONTON

One of the major costs of coal/heavy oil co-processing is incurred in the production of gaseous hydrogen. This valuable commodity is used to suppress the formation of coke in the co-processing reactor and to upgrade the products of the co-processing reaction. Currently, hydrogen is obtained by steam reforming of natural gas, but a less-expensive source of hydrogen would significantly enhance the economics of co-processing.

In an earlier study at the University of Alberta, which was funded by A/CERRF, natural gas under high pressure was used directly as a hydrogenation agent. In the presence of tetralin and Fe_2O_3 catalyst, natural gas (methane) caused Highvale subbituminous coal to be converted to toluene-soluble products in quantities that were equal to, or greater than, those produced when hydrogen gas was used. This suggested that substitution of methane for hydrogen would make co-processing more economically attractive if comparable product quality and yield could be achieved.

In a new project at the University of Alberta, the objective was to determine the yields and product qualities from the combined processing of coal, heavy oil and natural gas, and provide the data necessary to evaluate the feasibility of the combined processing concept.

Two types of reaction conditions were studied: coal liquefaction at 450°C using tetralin as a solvent, and co-processing of Highvale coal and Cold Lake bitumen at 410° or 430°C. All experiments were carried out with gaseous hydrogen, nitrogen or methane at cold pressures that varied from 1 000 to 1 500 psia in the presence of the Fe_2O_3 catalyst.

Some experiments used ^{13}C-labelled methane to determine whether incorporation of the gas into the liquid products was significant. Reactions were carried out in a 150 mL autoclave reactor and an 8 mL microreactor.

Initial experiments, using the microreactor and co-processing conditions, produced encouraging results with methane. The product quality and yield of light products (ethane to octane) was higher when methane was used, whereas a heavy, tarry material resulted when hydrogen was used.

When these experiments were repeated in the larger autoclave, however, co-processing in the presence of either nitrogen or methane produced inferior results compared with the use of hydrogen. The isotope experiments showed that no detectable gas-phase methane was incorporated into the liquid products. The inconsistency between the microreactor and autoclave results was believed to have been caused by the time required to reach the desired reaction temperature. Whereas the microreactor reached 430°C in less than five minutes, it took 30 to 40 minutes for the autoclave to reach the same operating temperature. Gas pressure may have been a factor, as well.

All the funding for this project was provided by the Alberta Office of Coal Research and Technology.

Publication

Gray, M.R., N.O. Egiebor and K. Muehlenbachs. 1991. Combined Processing of Coal, Bitumen and Natural Gas. Final Report. University of Alberta.

Co-processing of Coal and Bitumen with Molten Halide Catalysts

UNIVERSITY OF CALGARY (A. CHAKMA), CALGARY

It has been reported in the scientific literature that molten halide catalysts are excellent at cracking coal- and bitumen-related chemical structures.

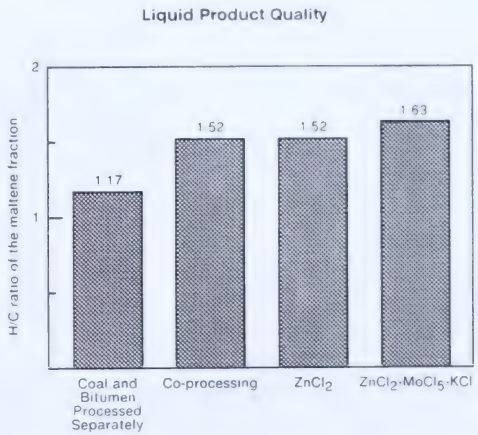
When coal is co-processed with bitumen, better solvolytic effects result. Therefore, when coal and bitumen are co-processed in the presence of a catalyst that has excellent cracking activity towards both feedstocks, better results in terms of product yield should be obtained. No work in this regard has been reported in the literature.

In this project, conducted at The University of Calgary, upgrading experiments were carried out in a batch autoclave. This was done to study the effectiveness of molten halide catalysts on the simultaneous liquefaction of a subbituminous coal and upgrading of Athabasca bitumen. Several halide catalysts were examined, including $ZnCl_2$, CuCl, KCl and $MoCl_5$. Two methods of catalyst addition to the reaction slurry were compared.

Impregnation of the coal with a catalyst-saturated methanol solution was found to be more effective than direct addition of the pulverized catalyst. The effect of different variables, such as temperature, reaction time and catalyst quantity were studied. The optimum temperature and reaction time were found to be 400°C and two hours, respectively. Under these conditions, a net coal conversion of 75 per cent of the dry, ash-free (daf) coal was achieved using $ZnCl_2$ catalyst. The yield of maltenes was 65.75 per cent of the daf feed, while the yields of coke, asphaltene and gases were 16.42 per cent, 7.34 per cent and 10.49 per cent, respectively.

A combination of different catalysts provided even greater liquid conversion (over 80 per cent). Based on these experiments, a combination of $ZnCl_2$-KCl-$MoCl_5$ catalysts was found to be the most effective. For this catalyst combination, the liquid yield was 75.9 per cent by weight of the daf coal. Coke and gas yields were 16.75 per cent and 7.35 per cent, respectively.

All the funding for this project was provided by the Alberta Office of Coal Research and Technology.



Publication

Chakma. A. 1991. Coprocessing of Bitumen and Coal with Molten Halide Catalysts. The University of Calgary.

Co-processing of Coal and Heavy Oil in Alberta, Phase II

ALBERTA OIL SANDS TECHNOLOGY AND RESEARCH AUTHORITY, CALGARY

In August 1988, an "interest group"[1] was formed to review the potential for commercializing coal/heavy oil co-processing.

At the time, several feasibility studies had indicated that co-processing is a less-expensive method than direct liquefaction for producing synthetic fuels from coal, and it might even be an alternative to the current method for upgrading heavy oil/bitumen to synthetic crude oils. Therefore, the interest group initiated a two-phase investigation to identify the relative merits and economics of coal/oil co-processing compared to heavy oil upgrading. The study also examined strategic factors affecting commercial development of co-processing technologies in Alberta.

The first phase of the project was completed in 1989. Under the leadership of the Alberta Oil Sands Technology and Research Authority (AOSTRA), and with technical and financial contributions from the participants, it was found that the economics of co-processing are almost equivalent to those of heavy oil upgrading at today's feedstock prices. The strategic factors that can have a significant effect on the commercial development of co-processing are: feedstocks, plant location, infrastructure, technology and plant capacity.

The second phase of the work began in 1990/91. It was subdivided into four separate subprojects according to the following topics:

·Location and Infrastructure;

·Refinery Integration;

·Environmental and Regulatory Issues; and

·Marketing Analysis.

The overall objective of Phase II was to define and explore the opportunities in Alberta that will initiate a pioneering commercial co-processing venture in Alberta. Investigations of the four individual components of this task were carried out by Monenco Consultants Limited, Kilborn Engineering Alberta Limited and Purvin & Gertz Inc. An overall summary report was prepared by AOSTRA.

The objective of the Phase II investigation carried out by Monenco Consultants Limited was to determine the site for a heavy oil/coal co-processor that would incur the lowest possible costs for feedstock and infrastructure. Considered were two existing coalmine/power plant complexes (Sundance/Keephills and Battle River), two proposed coalmines near Picardville and Dodds/Round Hill, sites near Edmonton where by-product hydrogen is available, and a heavy oil production site near Cold Lake.

Each of the mines was assessed for its ability to supply up to 1.3 million tonnes a year of one of the feed materials--low-ash (maximum 10 weight per cent) subbituminous coal--while the other major component--heavy oil--would be supplied at a heavy oil processing plant or from a pipeline.

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[1]Phase I participants were: Canadian Occidental Petroleum Ltd., Alberta Power Limited, Gulf Canada Resources Limited, Husky Oil Operations Ltd., Shell Canada Limited, TransAlta Utilities Corporation, Amoco Canada Petroleum Company Ltd., Mitsui SRC Development Co. Ltd., Saskatchewan Energy and Mines, Alberta Oil Sands Technology and Research Authority, and the Alberta Office of Coal Research and Technology.

Phase II participants are: Canadian Occidental Petroleum Ltd.,Husky Oil Operations Ltd., Mitsui SRC Development Co. Ltd.,TransAlta Utilities Corporation, Canadian Energy Developments Inc., Esso Resources Canada Limited, PanCanadian Petroleum Limited, Manalta Coal Ltd., VEBA Oel, Alberta Research Council, CANMET, Alberta Oil Sands Technology and Research Authority, and the Alberta Office of Coal Research and Technology.

The third component of the feed stream--hydrogen--would be produced from natural gas or water, or be supplied when available as a by-product from nearby chemical plants. All these feedstocks would be used in a co-processing plant that would begin operation in the year 2000 and continue operating for 25 years.

An examination of the infrastructure costs for a "pioneer" demonstration plant capable of processing 10 000 barrels per stream day (BPSD) showed that any site that is located near the existing heavy oil pipeline from Cold Lake to Edmonton has a clear advantage over sites that are some distance from the pipeline. Also, it is important to be near coalmines to take advantage of the developed infrastructure and lower coal costs.

The Monenco study found that the best option for achieving the least-cost feedstock and infrastructure would take advantage of by-product hydrogen from a chemicals manufacturing plant (for example, the Dow or Celanese plants in Fort Saskatchewan or Edmonton, respectively), or be integrated with the Esso Strathcona refinery in east Edmonton. Coal would be supplied from nearby coalmines at Picardville or at Dodds/Roundhill. Mines at either location are believed capable of supplying coal having an ash content that is less than 10 weight per cent.

For a larger (65 000 BPSD) plant, it was found that there were no cost advantages for any particular site, although coalmine sites near the existing heavy oil pipeline had a slight advantage.

In a study carried out by Kilborn Engineering Alberta Limited, the technical and economic merits of building a co-processing plant and integrating it directly with an existing oil refinery were examined.

Two co-processing technologies were considered: Canadian Energy Development's (CED) counterflow reactor process, and the Hydrocarbon Research Inc. (HRI) catalytic two-stage process. Each of these would process subbituminous coal and Cold Lake heavy oil.

The four major petroleum refineries that operate in Alberta were considered as potential sites for the integrated co-processor, but the Strathcona refinery of Esso Petroleum Canada Limited in Edmonton was chosen as the most suitable.

The reasons given for this choice are as follows:

- an ability of the co-processor to process additional Cold Lake heavy oil or other heavy, sour crude oils in a refinery that was designed to process light, sweet crude oils;
- an ability of the co-processor to upgrade pitch from existing crude oil units and cracker fractionator bottoms to distillate fuels, rather than disposing of it as a "low value" product, such as bunker fuel;
- an ability of the co-processor to upgrade simultaneously the low-quality, intermediate distillate streams, such as low-cetane light-cycle gas oil (LCGO) and sour distillates from the asphalt unit, to high-quality distillate products or cracker feedstock; and
- an ability to tailor the quality of the products from the co-processor to meet the specific requirements of the refinery.

Examination of the technical aspects of the two co-processing schemes indicated that both could produce a high-quality synthetic crude oil, the components of which would meet or exceed Esso's specifications and allow efficient processing without modifying the refinery. Also, improved production of diesel fuels would result.

In another investigation carried out by Kilborn, the environmental and regulatory issues associated with establishing a co-processor at four locations were assessed. Those locations were: the existing Highvale coalmine and associated Keephills power plant, the greenfield coalmines at Picardville and Dodds/Round Hill, and the Esso Strathcona refinery.

In considering all the various effects that each operation has or would have on the environment, and the effects that would arise from locating a co-processor at each facility, it was concluded that placing the co-processor at either the Highvale-Keephills complex or the Strathcona refinery would be the best option.

The final investigation that formed part of this study was undertaken by Purvin & Gertz Inc. This firm carried out a marketing analysis of synthetic crude currently available in Alberta, and made recommendations about any process that might be used to produce a similar product in the future.

It was stated that the synthetic crude oil now produced from the two oil sands projects in Alberta has saturated the Canadian market. This is largely owing to the characteristics of synthetic crude that require certain adjustments to be made at those refineries which use it. Also, some price discounting is occurring at U.S. refineries that use some Alberta synthetic crude oil. This has affected the prices for all synthetic crude oil. Thus, it is believed that any new synthetic crude oil should possess superior characteristics that will permit existing refineries to use more of it.

It was noted that the products of the co-processing technologies studied in this investigation could be improved in upgrading steps, and should attract a premium price by the year 2000 in comparison with current synthetic crude and light crude oils.

Overall, it was concluded that the $1.8 - $2 billion needed to build a commercial-scale co-processing facility could be raised only by creating a consortium of industry and government. A first step toward this goal should be the construciton of a demonstration plant in east Edmonton.

Specialty Chemicals from Coal-Derived Liquids

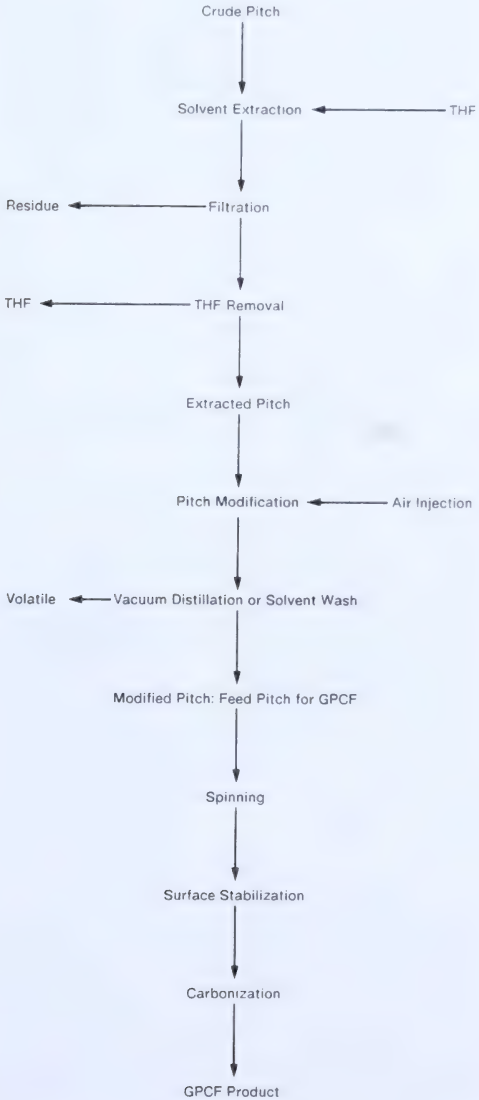
ALBERTA RESEARCH COUNCIL, DEVON

Both the distillable and non-distillable liquid products from coal conversion processes are capable of providing polycondensed aromatic feedstocks for value-added products, such as carbon fibres and fine chemicals. Thus, a project was begun in 1989/90 at the Alberta Research Council (ARC) to develop processes for the production of chemical intermediates for the fine-chemicals and polymer industries, and the manufacture of carbon fibre from pitch for advanced composite materials. Both these activities might lead to the creation of a coal-based secondary industry in Alberta.

In particular, the project focused on methods for using the non-distillable fraction (pitch) to produce industrial-grade, or general purpose, carbon fibre (GPCF). This material is being used increasingly in products such as reinforced concrete and engineering plastics employed in automobiles, and as a replacement for asbestos.

Carbon fibre production requires several steps. These include pitch treatment, filament spinning, filament stabilization and final heat treatment. In the Alberta Research Council study, various options within these steps were examined, including pitch modification, measuring the viscosity of modified pitch, the equipment for making filaments, and conditions for stabilizing the surface of filaments.

Process for GPCF Production from Battle River Coal-Derived Pitch



A final product was obtained, and its physical properties were judged to be comparable to those of commercial-grade GPCF.

Consequently, a new project was begun this year under the title "Process Development for Carbon Fibre from Coal-Derived Liquids." It is described separately in this report.

Regarding the distillable fraction derived from coal, it is known that compounds containing two to five polycondensed aromatic rings are present, and random locations of alkyl side-chains on aromatic rings give a mixture of isomers. If these side-chains are removed, however, the products can be isolated readily by conventional separation techniques. These components could be used as intermediates for further synthesis of final products, such as fine chemicals, monomers for unique plastics and pharmaceuticals.

In studying various processes for the de-alkylation of coal-derived distillates, ARC researchers found one set of promising conditions. It produced naphthalene (25.3 per cent), indene (16.5 per cent), and 2-methylnaphthalene (11.6 per cent).

All the funding for this project was provided by the Alberta Office of Coal Research and Technology.

Publications

Ohuchi, T. and A.K. Chambers. 1991a. Production Capacity of Carbon Fiber and Industrial Application of General Purpose Carbon Fiber. Alberta Research Council.

Ohuchi, T. and A.K. Chambers. 1991b. Literature Review: Production Capacity of Carbon Fibre and Industrial Application of General Purpose Carbon Fibre (GPCF). Alberta Research Council.

Ohuchi, T., B. Croy and A. Chambers. 1991a. Specialty Chemicals and Carbon Fibre from Coal Derived Liquids. Alberta Research Council.

Ohuchi, T., B. Croy and A. Chambers. 1991b. Carbon Fiber and Chemicals from Coal Derived Liquids. Presented at Alberta Coal Research Contractors' Conference, Calgary, October 31. Alberta Research Council.

Ohuchi, T., M. Carmichael and A. Chambers. 1990. Specialty Chemicals and Carbon Fibre from Coal Derived Liquids. Alberta Research Council.

Process Development for Carbon Fibre from Coal-Derived Liquids

ALBERTA RESEARCH COUNCIL, DEVON

In the earlier project, "Specialty Chemicals from Coal-Derived Liquids", it was learned that the ultimate quality of carbon fibres depends on the nature of the pitch from which the fibres are made. Furthermore, the suitability of a pitch for making carbon fibres appears to be a function of its viscosity. Thus, one objective of this second project at the Alberta Research Council (ARC) was to develop methods for modifying pitch to achieve a desired melting point above 180°C. A second objective was to find methods for producing carbon fibres from this modified pitch that possessed good "melt-spinning" properties.

The previous project showed that production of carbon fibre from coal-derived pitch involves the following steps:

- solvent extraction of crude pitch to remove ash, unreacted coal and coke;
- modification of the extracted pitch to obtain a raw material having an optimum melting point and viscosity;
- filament production using a spinning process;
- oxidization of the surface of filaments to prevent them from fusing during subsequent thermal treatment; and
- carbonization under an inert atmosphere.

Using pitch which was made at the NEDOL coal liquefaction plant in Japan and derived from Battle River subbituminous coal, a satisfactory modification process was developed that involved air injection into the feed pitch at 300°C under reduced pressure. This material subsequently demonstrated that it had suitable characteristics for fibre spinning and felt making to produce general purpose carbon fibre (GPCF).

Three methods for continuously making carbon fibre filaments in the laboratory were examined. Two were used in this study. One employed an air attenuated nozzle, while the other was a modified candy floss machine.

The air attenuated nozzle produced filament that could be wound on a bobbin, whereas the candy floss machine produced a mass of fibres called "felt", which resembled cotton candy.

The surfaces of the filaments made by both processes were stabilized by oxidizing with air or oxygen at 150°-200°C. The fibres were then carbonized by heating to 1 000°C under a nitrogen atmosphere.

Although the fibres produced in this experiment were somewhat thicker than commercially available products (tensile strength decreases with thickness), the tensile strength of the ARC fibres compared favourably with the commercial products. It was concluded, however, that the production equipment should be modified to produce filaments having a diameter of 10 to 15 μm, instead of 30 to 50 μm, which was the case in this study.

It was concluded that the process developed at ARC for producing GPCF should be commercialized in collaboration with private enterprise. It was also suggested that the principal user for this material would likely be the cement industry, which may use carbon fibres for reinforcing cement.

Funding for this project was provided by Alberta Research Council and the Alberta Office of Coal Research and Technology.

Publication

Ohuchi, T., B. Croy, A. Chambers and G. Kovacik. 1992. Process Development for General Purpose Carbon Fibre (GPCF) from Coal Derived Liquids. Alberta Research Council.

Coal/Oil Co-processing Using a Counterflow Reactor

CANADIAN ENERGY DEVELOPMENTS INC., EDMONTON[1]

Since 1984, Canadian Energy Developments Inc. (CED) of Edmonton has been developing processes for upgrading Alberta's sizeable reserves of heavy oil, bitumen and subbituminous coal, and mixtures of these energy resources.

The experimental work was performed initially on a bench-scale unit (BSU), and then on larger process development units (PDU), to develop technologies for heavy oil upgrading, heavy oil/coal co-processing and coal liquefaction. In particular, the PYROSOL and CCLC co-processing methods for making synthetic crude oils from Alberta subbituminous coals and bitumen were developed.

Concurrent with the refinements being made by CED to these technologies, another promising process has been evolving in Germany at Gesellschaft für Kohleverflüssigung mbH (GfK), a company with which CED has technology agreements. GfK showed that use of a counterflow reactor (CFR) system has certain inherent advantages over the co-current, upflow reactor technology used until now by CED and other process developers.

In the CFR system, the oil/coal slurry enters the top of the reactor and flows downward countercurrent to the upflowing recycle hydrogen and product vapours. The product vapours and other gases are withdrawn from the top of the reactor, and unconverted coal, "solids" and liquid hydrocarbons are removed from the bottom of the reactor under level control.

The German tests showed that a counterflow reactor is capable of performing equally well in direct coal liquefaction, co-processing and heavy oil upgrading.

Thus, a project was initiated in Edmonton to test the counterflow process with Alberta coal and heavy oil. The PDU that was used for the PYROSOL and CCLC investigations was modified to the counterflow configuration and several continuous, long-duration reactor runs were completed. One of these lasted approximately 400 hours. Distillable oil yields of 69 to 71 weight per cent (daf) were achieved from 60 weight per cent Cold Lake vacuum bottoms and 40 weight per cent Vesta subbituminous coal. This 400-hour run demonstrated that the counterflow reactor was suitable both for co-processing and for efficient recovery of the produced exothermic heat.

Operation of the PDU demonstrated the key advantages of the CFR technology over the co-current reactor.

[1]This project was funded by Canadian Energy Developments Inc., Alberta Oil Sands Technology and Research Authority, and the Alberta Office of Coal Research and Technology.

They are:

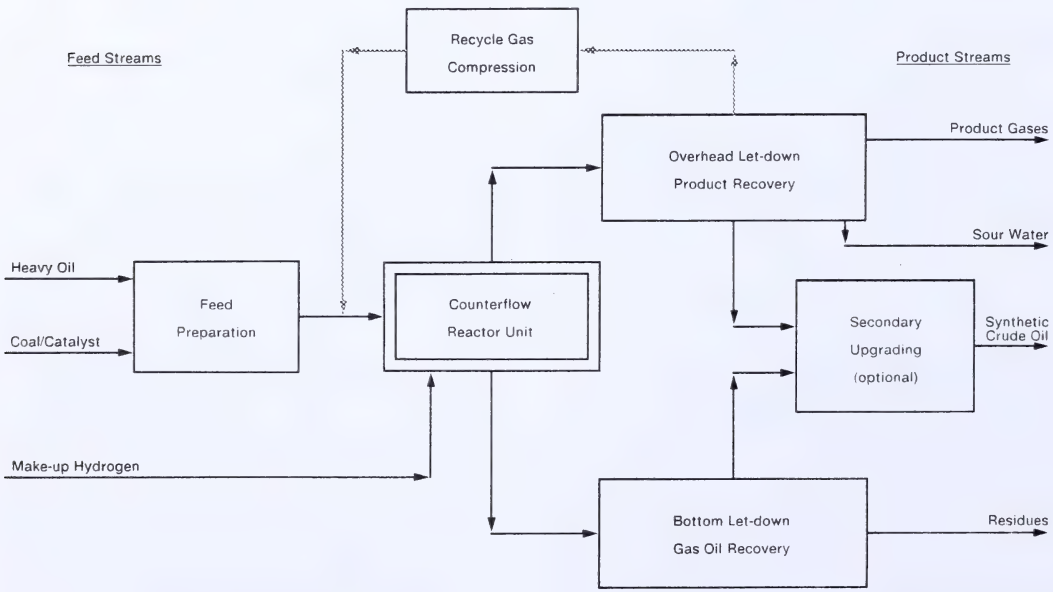
- no concerns about the settling of solids, because liquids and solids are removed from the bottom of the reactor;
- optimum internal recovery of the exothermic heat of reaction, resulting in less severe feed preheating;
- a favourable profile for the hydrogen partial vapour pressure; and
- lower superficial gas velocities than were required in the co-current reactor configuration.

Conceptual commercial-sized upgrading facilities were designed on the basis of the test results. For an Alberta location, capital and operating costs were estimated. These, together with the annual revenue, form the basis for economic feasibility studies. For a 20 per cent DCF-ROE (60/40 debt/equity) a "window of opportunity" opens for co-processing once the heavy oil price rises above approximately $15.50/bbl ($100/m^3).

Publication

Canadian Energy Developments Inc. 1991. Counterflow Reactor Development Project.

Schematic of Counterflow Reactor Pilot Plant



Counterflow Reactor Development, Phase II

CANADIAN ENERGY DEVELOPMENTS INC., EDMONTON[1]

Following the succesful demonstration of counterflow reactor (CFR) technology at the PDU scale, Canadian Energy Developments (CED) undertook a second project to participate in the demonstration of CFR at a larger scale.

A 4 t/d pilot plant in Germany belonging to Gesellschaft für Kohleverflüssigung mbH was modified by replacing the existing upflow reactor with a counterflow reactor having an internal diameter of 400 mm and equipped with a mechanical stirrer. Advice about the modification was provided by CED.

The reactor was then tested by upgrading some residual and waste oils. For comparison, the same oils were upgraded in a separate co-current upflow reactor (CCR).

It was found that comparable yields of distillable oils were obtained from both reactors, but in the CFR this was achieved at temperatures that were approximately 15°C below those in the CCR. In addition, the CFR produces significantly lower amounts of product gas, which is reflected in a lower consumption of hydrogen. One additional advantage of CFR over CCR--the ability to recover exothermic heat--was apparent as a reactor operating temperature of 415°C could be maintained with a feed temperature of 300°C.

It was concluded that tests should be initiated using Alberta feedstocks.

Publication

Canadian Energy Developments Inc. 1992. Counterflow Reactor Development Project, Phase II, Final Report.

[1]This project was funded by Canadian Energy Developments Inc. and the Alberta Office of Coal Research and Technology.

Coal Research Contractors' Conference

On October 30 and 31, 1991, the Alberta Office of Coal Research and Technology sponsored a conference on coal research projects funded by the Office. This was the third such conference; all were held in Calgary. Twenty-two presentations were made to an audience of 69 attendees. Based on an enthusiastic response from those who attended, another similar conference is planned for 1992.

Titles of the conference presentations are listed on the next page. Conference proceedings were produced by the Alberta Geological Survey, and may be obtained from them on request. Ask for "ARC Information Series 117." All requests should be directed to:

Alberta Research Council
Publications Office
250 Karl Clark Road
P.O. Box 8330, Station F
Edmonton, Alberta, T6H 5X2

Telephone: (403) 450-5390

Coal Geology

Predicting Geotechnical Parameters from Geophysical Logs - Experience from Surface Mines in Western Canada, *N.H. Wade*

Applied Surface Geophysical Applications: The Foothills and Mountain Coalfield Experience, *A. Peach and K. Cochrane*

Geology and Coal Resources of the Cadomin Mapsheet (83F/3), Alberta, *W. Langenberg*

Coal Quality and Production

GSIS Supported Coal Resource Mapping in Alberta, *R. Richardson, et al.*

Coal Quality Modelling Using Fuzzy Techniques, *S. Treasure and D. Nikols*

Thick Seam Mining Demonstration Project - Research Aspects, *J. Kulach and H. Sandkuhler*

Coal Preparation

Novel Application of Oil Agglomeration Technology, *Y. Briker, et al.*

Agglomeration Demonstration Project at Smoky River Coal, *E. Horner and D. Fawcett*

Application of Electrocoagulation to Tailings Reclamation, *J. Donini, et al.*

Coal Transportation and Slurries

Particle Distribution in Slurry Flow Through Tees and Manifolds, *H.A. Nasr-El-Din and J.H. Masliyah*

Pipeline Transportation of Alberta Coals as Liquid Hydrocarbon Slurries, *T. Frankiewicz and G. Perry*

Coal Combustion and Gasification

H_2S Capture in Coal Gasification Using Calcium Based Sorbents, *G. Kovacik, et al.*

Properties and Possible Uses of High-Volatile Bituminous Coal Valley Coal Char, *R.C. Joshi and P.V. Sivapullaiah*

Evaluation of IGCC for Canadian Utility Applications, *M.M. McDonald*

The Coal Association of Canada IGCC Feasibility Study, *R.F. Geosits, et al.*

Coal Utilization and Environment

Use of Gypsum As Flocculent for Treatment of Mine Effluent Waters, *C. Bateman*

LNS-CAP Project, *B. Simonson*

A Review of Potential CO_2 Disposal/Utilization Technologies, *M.M. McDonald*

Non-Conventional Coal Processing

Co-processing of Bitumen and Coal with Molten Halide Catalysts, *A. Chakma*

Counterflow Reactor (CFR) for Upgrading of Heavy Oil/Coal Slurries, *D. Berger, et al.*

New Uses for Coal

Coal-Bed Methane - An Alberta Opportunity, *B.A. Rottenfusser, et al.*

Carbon Fibres from Alberta Coal-Derived Liquids, *T. Ohuchi, et al.*

Coal-Fired Steam Generation for Heavy Oil Recovery, *K. Firmin*

Gasification

Because coal is used to produce more than 90 per cent of Alberta's electrical power, the economic and environmental importance of efficient power generation from coal will be crucial to Alberta's development for the foreseeable future.

Integrated Coal Gasification Combined Cycle (IGCC) is regarded by the power-generation industry as the technology of choice for future electrical power production from coal. IGCC is being seriously considered by industry because it is economically competitive with conventional coal-combustion systems, and it has demonstrated unparalleled performance in emission control. IGCC offers the ability to reduce NO_x and SO_x emissions below levels currently required by regulation or recommended by guidelines. Also, the increased efficiency of IGCC relative to other coal-based technologies results in approximately 15 to 20 per cent less carbon dioxide production per unit of electrical output. Current IGCC technology can permit almost complete removal of CO_2 from the stack gas, if required.

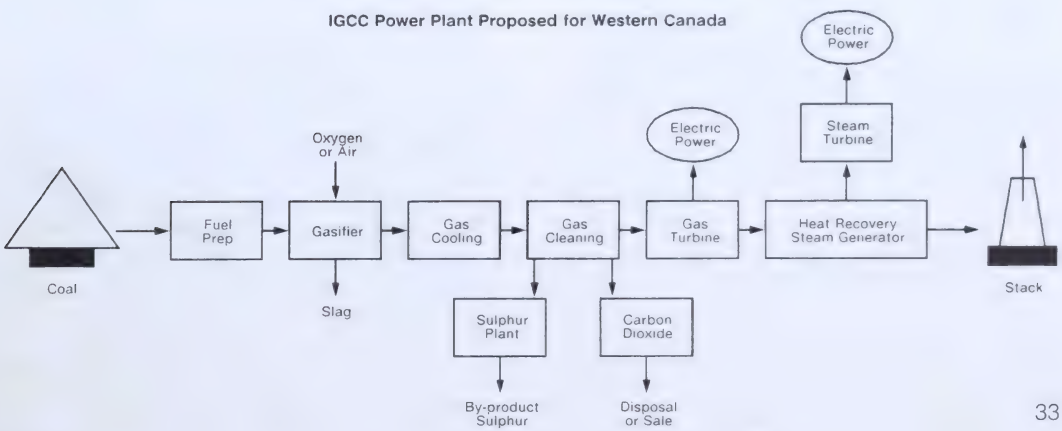
Alberta's coals are unique in that they have a low-sulphur content and high reactivity. Most current IGCC technologies, however, have been developed for coals that contain more sulphur and are less reactive. Therefore, given the world-wide interest in gasification, a major research effort has been under way in Alberta to determine the behaviour of Alberta coals when used in several gasification technologies.

Thus far, 16 projects in this program have been initiated.

Three projects active in 1991/92 are described in the following section, and one additional project was supported under the Western Canadian Low-Sulphur Coal to Ontario Program.

Gasification projects completed thus far are described in three technology transfer booklets: *Gasification of Western Canadian Coals; Gasification of Alberta Coals;* and *Some Recent Studies of Coal Combustion and Gasification.* Also, the publication *Development of Clean Coal Technologies for Alberta* contains information on Integrated Gasification Combined Cycle processes. All four publications are available from Alberta Energy/Forestry, Lands and Wildlife information centres in Calgary and Edmonton.

IGCC Power Plant Proposed for Western Canada



Canadian Coal Gasification Project (CANMET/ARC)

CANMET, OTTAWA

For several years, an informal group of industry, academic and institutional researchers and research supporters has been investigating various aspects of coal gasification, with particular emphasis on Integrated Combined Cycle Gasification (IGCC). This group, currently called the Canadian Gasification R&D Steering Committee, decided in 1990 that many of the original objectives of the committee had been met. Therefore, new research priorities were established. Those priorities are:

- evaluate materials;
- model IGCC and gasification processes;
- quantify emissions;
- evaluate fuels preparation;
- conduct gasification tests;
- optimize designs; and
- evaluate uses for by-products.

In 1991, the committee proposed that the Canadian Coal Gasification Project (CANMET/ARC) be launched. Subsequently, several research studies under this project were approved by the Office for funding. They include studying the durability of materials, investigating environmental considerations and plant efficiency, and examining methods for preparing coal feedstocks. Included among the environmental aspects are investigations of methods for controlling and reducing emissions, as well as process enhancements to capture and use impurities, and to produce inert waste products.

At year-end, nine individual studies had begun.

The Canadian Coal Gasification Project (CANMET/ARC) is being supported by: TransAlta Utilities Corporation, SaskPower, Alberta Power Limited, Ontario Hydro, Nova Scotia Power Corporation, Alberta Research Council, Nova Scotia Department of Natural Resources, the Cape Breton Development Corporation, Environment Canada, CANMET, and the Alberta Office of Coal Research and Technology.

Gasification Properties of Alberta Coals

ALBERTA RESEARCH COUNCIL, DEVON

For the past three years, investigations have been carried out at the Alberta Research Council to find an inexpensive disposable sorbent for use in removal of pollutant species from gasifiers operating with low-sulphur Alberta coals. This substance would be used in a sorbent injection system and could improve considerably the efficiency and economics of coal gasification processes. The principal pollutants of interest are hydrogen sulphide, carbonyl sulphide and ammonia.

In earlier laboratory-scale studies, it was found that calcium-based sorbents were the most promising for capture of sulphur species produced by coal gasification.

It was reasoned from this earlier work that sorbent injection would be more effective if the sorbent were injected downstream from, or not directly into, the high-temperature flame zone. Thus, in co-operation with CANMET, a pilot-scale gasifier at the CANMET Bell's Corners laboratory was used to test limestone injection. A sorbent injection unit was built and sent to the CANMET laboratory, where an Alberta Research Council staff member participated in the limestone injection tests involving the gasification of Highvale coal.

CANMET Sorbent Injection Results:
Low-Sulphur Subbituminous Coal - Highvale

	Sorbent Injection Point		
	Secondary Burner	Sight Window	No Limestone
Carbon Conversion, wt%	83	88	83
Ca/S, mol/mol	3.5	6.0	0.0
Sulphur Retained in Char/Ash, wt%	95	60	50
Estimated SO_2 Emission*, ng/J	10	80	100

CANMET Sorbent Injection Results:
High-Sulphur Bituminous Coal - Donkin

	Sorbent Injection Point	
	Secondary Burner	No Limestone
Carbon Conversion, wt%	82	80
Ca/S, mol/mol	1.0	0.0
Sulphur Retained in Char/Ash, wt%	40	20
Estimated SO_2 Emission*, ng/J	500	1000

*SO_2 emission if the product gas was combusted in an IGCC plant, ng of SO_2 per joule of input fuel (high heat value).

(Source: Kovacik, G., D. Fong, D.E. Ungarian and A.K. Chambers. 1991. Gasification Properties of Alberta Coals. Alberta Research Council.)

The sorbent injection test unit was used to test three potential sorbents: metallurgical red mud, power plant flyash and water treatment sludge.

The most promising results obtained during this project were with the water treatment sludge. In addition to its effectiveness as a sorbent, use of this chemical would consume a material that otherwise causes storage and disposal problems.

These experimental observations with water treatment sludge were supported by an evaluation of existing gasification data for equilibrium prediction of sulphur capture when limestone is used as a sorbent. Using F*A*C*T software developed at the University of Montreal, it was calculated that 95 per cent of the sulphur present in the gas resulting from the gasification of Highvale coal could be captured when water treatment sludge is used as a sorbent.

All funding for this project was provided by the Alberta Office of Coal Research and Technology.

Publications

Kovacik, G., A.K. Chambers and B. Özüm. 1989. Gasification Characterization of Alberta Coals. Alberta Research Council.

Kovacik, G. A.K. Chambers and B. Özüm. 1988a. Staff Training: Gasification Process Research. Alberta Research Council.

Kovacik. G., A.K. Chambers and B. Özüm. 1988b. Study of Fundamental Gasification Properties of Alberta Coals. Alberta Research Council.

Kovacik, G., A.K. Chambers and B. Özüm. 1988c. Gasification Characterization of Alberta Coals. Alberta Research Council.

Kovacik, G., A.K. Chambers and B. Özüm. 1988d. Laboratory-Scale Facilities to Study Gasification Properties of Alberta Coals. Alberta Research Council.

Kovacik, G., D. Fong, D.E. Ungarian and A.K. Chambers. 1991. Gasification Properties of Alberta Coals. Fiscal Year 1990/91. Alberta Research Council.

Kovacik, G., M. Malychuk, B. Özüm, D.E. Ungarian and A.K. Chambers. 1989. Gasification Properties of Alberta Coals. Alberta Research Council.

Kovacik, G., M. Oguztöreli, A.K. Chambers and B. Özüm. 1990. Equilibrium Calculations in Coal Gasification. Int. J. Hydrogen Energy, 15:2, 125-131.

Kovacik, G., B. Özüm and A.K. Chambers. 1989. Gasification Properties of Alberta Coals. Alberta Research Council.

Kovacik, G., B. Özüm, D.E. Ungarian and A.K. Chambers. 1990. Gasification Properties of Alberta Coals. Alberta Research Council.

Canada/Japan Collaboration on Coal Gasification Research

ALBERTA RESEARCH COUNCIL, DEVON

In 1981, Japanese and Canadian researchers reached agreement on a collaborative program to carry out coal liquefaction research and development. Canadian involvement in this program is coordinated through CANMET.

Since 1981, this program has focused on coal conversion, but in recent years the emphasis has begun shifting toward coal gasification.

Following a visit to Japan in 1988 by a team of Canadian coal researchers, it was observed that the Japanese were making significant strides in coal gasification research, and that every effort should be made to have Canadian coals included in tests carried out there.

While the Office has supported the involvement of Alberta Research Council staff in past Canada/Japan coal conversion activities, it was decided this year to initiate a separate project specifically for collaborative gasification work.

The principal objectives are to monitor and encourage gasification research programs in Japan, arrange and attend meetings, ship coal samples to Japan, and inform the Alberta coal industry of technical developments in this field.

This collaboration has included evaluation by Japanese researchers of the suitability of five Canadian coals for gasification processes. The evaluation resulted in the selection of one Alberta coal for testing on a pilot-scale air-blown gasifier in Japan. The results of this test demonstrated the suitability of the Alberta coal for gasification.

All the funding for this project was provided by the Alberta Office of Coal Research and Technology.

Publications

Kovacik, G. 1992. Canada/Japan Collaboration on Coal Gasification Research. Alberta Research Council.

Silveston, P.L. 1989. Coal Conversion Research in Japan. Report of the Canadian Visiting Team.

Environment

Environmental issues must be addressed in each of the projects funded by the Alberta Office of Coal Research and Technology, whether the concern is land reclamation, habitat disturbance or the discharge of contaminants into water bodies or the atmosphere.

This is consistent with a growing awareness by Alberta's coal producers that economic development and environmental protection must proceed hand-in-hand. For example, when mining activities cease in open-pit mines, the previously removed overburden must be replaced in such a manner that native vegetation or crops can be grown, or some alternative reclamation scheme must be used. Also, in considering future electricity-generating technologies for Alberta, utility companies find coal gasification to be attractive, partly because it produces fewer air emissions. One of the most important advantages of using low-sulphur Alberta coal in Ontario is that fewer sulphur oxides will be produced during combustion. These are but a few examples of the environmental considerations inherent in each project supported by the Office.

Four projects wholly concerned with environmental aspects are described in the following section.

Use of Gypsum as Flocculent for Treatment of Mine Effluent Waters

TRANSALTA UTILITIES CORPORATION, CALGARY

The geological materials that overlie plains coal seams contain a high proportion of montmorillinite clays. As precipitation and groundwater come into contact with disturbed overburden materials at operating mines, these colloidal clays become suspended. This leads to mine effluent waters that are severely contaminated with suspended sediment. For example, suspended sediments in mine effluent waters at the Highvale Mine normally achieve levels of 2500 mg/L, which is 50 times the environmentally safe limit. At times, these levels rise to as high as 9000 mg/L.

The dominance of sodium ions in the groundwater exacerbates the problem by causing the clay particles to disperse. This results in a stable colloidal emulsion that will not settle and cannot be treated in conventional settling ponds. Ordinarily, situations such as this call for treatment by chemical flocculents, but this is an expensive option.

As an alternative, naturally-occuring gypsum (calcium sulphate) was investigated by TransAlta Utilities Corporation as a low-cost, environmentally safe means of flocculating suspended sediment from mine effluent before it was released to surface watercourses. Initial estimates suggested that use of gypsum could reduce the effluent treatment costs to 1/10th those anticipated if chemical flocculents were used.

In the first phase of the study, laboratory investigations were carried out at the Alberta Research Council to determine the dissolution rates of gypsum in the mine effluent, and the settling rates of clays in treated waters. These parameters were studied over a range of gypsum concentrations and expected seasonal temperatures.

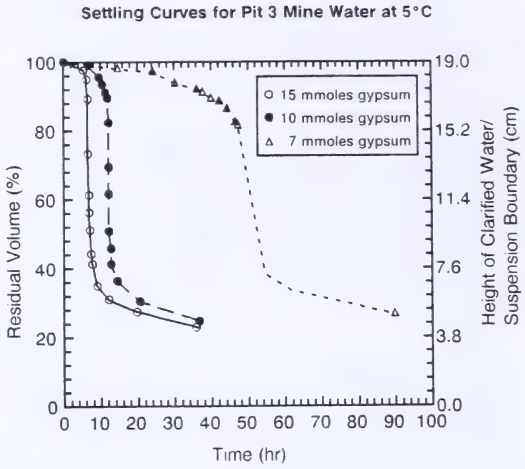
It was found that gypsum effectively flocculated the dispersed clay, and the treated water met both the Alberta Coal Mining Waste Water Effluent Guidelines and the Canadian Water Quality Guidelines for freshwater aquatic life for all important water quality requirements. The study also showed that the grade of gypsum made a difference in the dissolution rate, but 90 per cent of the less-expensive quarry grade could be dissolved within 60 minutes under mixing conditions that are practical in the field. This was deemed to be acceptable. Also, the temperature at which mixing took place had little effect on the dissolution rate, suggesting that winter conditions will not affect the operation appreciably.

The final step in this project was the preparation of a design for a pilot test facility. This was undertaken by Monenco Consultants Limited. Construction was anticipated to be under way during 1992.

Funding for this project was provided by TransAlta Utilities Corporation and the Alberta Office of Coal Research and Technology.

Publication

TransAlta Utilities Corporation. 1991. Gypsum as an Alternate Flocculent for the Treatment of Coal Mine Effluent Waters, Final Report.



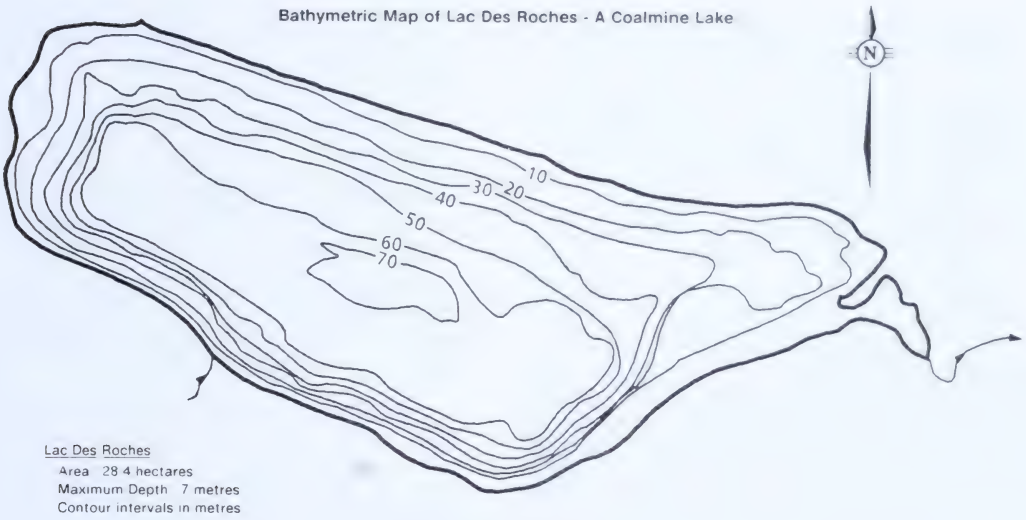
Development of Sport Fisheries in Lakes Created by Coalmining Operations in the Eastern Slopes

LUSCAR STERCO (1977) LTD., EDSON[1]

When coal extraction ceases in an Alberta surface mine, the open pit that remains must undergo some type of reclamation to restore the land to productive use. In mountain and foothills mines, much of the overburden is rock. This makes it either impractical or prohibitively expensive to fill in a pit.

In two of the coalmining areas where Luscar Sterco (1977) Ltd. and Cardinal River Coal Ltd. have operated mines, three of the former pits have been allowed to fill with water, and now they have become lakes. Because both companies plan to develop other lakes in the future, a study was initiated this year to

[1]Funding is being provided by Luscar Sterco (1977) Ltd, Cardinal River Coal Ltd., and the Alberta Office of Coal Research and Technology.



investigate the three coalmine lakes and one natural lake to assess how best to develop these types of lakes for sportfishing and other recreational pursuits.

Although sport fishery lakes have been created from mined areas for approximately 60 years in the U.S.A., the concept has not been seriously investigated until now in the foothills/mountain region of Alberta.

In the current study, the following activities are under way:

- characterizing and assessing the three coalmine lakes and the control lake for their suitability for sport fishery;
- identifying possible limiting factors for lake development;
- determining the time required for lakes to become stable;
- assessing levels of potentially harmful constituents, such as heavy metals; and
- evaluating various enhancement options to maintain or improve the coalmine lakes for fisheries habitat.

Thus far, a literature review and seasonal sampling of the three coalmine lakes were completed. Analysis of these samples and studies of lake limnology were under way at year-end.

The literature review showed that one of the most important elements for lake development is the need for a shallow, "littoral zone" around the edge of a lake. This is essential for providing the organisms that fish need for food, as well as the necessary protection during spawning and the early life stages of fish. This shallow zone is often missing from steep-sided pits, and provision for it during the final stages of mine development is viewed as very important.

Publication

Luscar Ltd. 1991. Development, Characteristics and Management of Surface Coal Mine Lakes. Literature Review. Progress Report #1.

CO_2 Disposal/Utilization Workshop

A one-day workshop, sponsored by the Office, was held in Calgary on May 29, 1991. Six presentations were made on carbon dioxide abatement, use and disposal. They were followed by a panel discussion meant to generate proposals for new research.

The workshop was attended by 52 representatives of industry and government, and 16 made commitments to participate in a group called the CO_2 R&D Coordination Committee. Subsequently, this committee has helped to disseminate information on the status of international CO_2 reduction measures and climate modelling that pertains to global warming. Also, the committee has accepted a mandate to foster new R&D projects in this area, and has already begun to develop a project that will examine the feasibility of CO_2 disposal in geological aquifers.

The 159-page proceedings of the workshop are available on request by contacting the Office at the address shown on p 72.

CO_2 Disposal Study - Phase II

ALBERTA OIL SANDS TECHNOLOGY AND RESEARCH AUTHORITY (CALGARY) AND OTHER PARTICIPANTS[1]

Current concerns about the effects that carbon dioxide might be having on global warming have given rise to numerous research projects world-wide on methods for recovering, using or disposing CO_2.

In this project, which began in mid-1991, the objective is to determine the feasibility of disposing 50 000 tonnes of CO_2 a year in a range of oil reservoirs in Alberta and Saskatchewan. If the situation warrants, the CO_2 might be used to enhance the recovery of oil from some of these reservoirs.

Three subprojects have been identified. They concern:

- the capture of CO_2 at sources that include coal-fired power plants, an ethylene plant, a sour gas plant and a hydrogen plant;
- analysis and predictions about the performance of light and heavy oil reservoirs in Alberta and Saskatchewan for enhanced oil extraction using CO_2; and
- the cost/benefit relationship for CO_2 recovery and use for each of the sources.

Work in all three subprojects was under way at year-end.

[1]A consortium of 25 companies and government agencies is funding the project, under the leadership of AOSTRA.

Greenhouse Gases R&D Program

INTERNATIONAL ENERGY AGENCY, UNITED KINGDOM

Nine countries, including Canada, are funding a three-year investigation by the International Energy Agency in London to assess technologies capable of reducing the amount of CO_2 produced per unit of energy output from power stations that use coal or other fossil fuels. Alberta is contributing through Energy, Mines and Resources Canada.

The candidate technologies either increase the thermal efficiency of combustion so that less CO_2 is produced, or capture the produced CO_2 and use or dispose of it. In this project, the feasibility of using various technologies will be determined. Proposals will then be prepared for further research, development and demonstration. The economic effects of implementing such technologies will be determined, with particular emphasis on the energy market.

The work will be based primarily on coal-fired systems, but oil- and natural gas-fired systems will be included where appropriate.

Enhanced Oil Recovery

In 1985/86, the Office and several companies financed a study entitled Fuel Options for Enhanced Oil Recovery. The investigation concluded that it was cost-effective for oil companies to use coal instead of natural gas to generate steam needed for enhanced recovery of heavy oil. The study also noted that to use coal successfully in heavy oil recovery schemes, a specially designed, pulverized coal-fired boiler was needed.

Subsequently, a Coal Use for Heavy Oil Recovery Technical Committee[1] was formed. It proposed a four-stage development program as the next step in using coal for heavy oil recovery. In the first stage of the program, two boiler manufacturers proposed designs for an innovative coal-fired steam generator. In the second stage, Combustion Engineering prepared an engineering design. Concurrently, the committee agreed to investigate the suitability of using the Low NO_x/SO_x Burner (LNSB) system being developed by TransAlta Resources Investment Corporation. This led to two projects. The first, Application of the LNS Burner to an Oil Field Steam Generator, was concluded previously. The other, LNSB Steam Generator Demonstration, was concluded this year.

Also included in this program were investigations of the merits of using slurry pipelining systems developed by Unocal Canada Limited to convey coal-condensate or coal-oil mixtures from Alberta coalmines to sites of heavy oil extraction operations.

Having achieved its objectives of developing and demonstrating the technology needed to use coal in place of natural gas for steam raising in heavy oil operations, the Committee was disbanded in 1990.

Progress thus far is described in the following Office publications: *Opportunities to Use Coal in Enhanced Oil Recovery,* and *Development of a Coal-Fired Boiler for Steam Injection in Heavy Oil Recovery.* In addition, some details about the Low NO_x/SO_x Burner are included in the publication, *Development of Clean Coal Technologies for Alberta.* All three are available from the Alberta Energy/Forestry, Lands and Wildlife information centres in Calgary and Edmonton.

[1]In addition to the Office, Committee members were: Esso Resources Canada Limited, Fording Coal Limited, Luscar Ltd., TransAlta Utilities Corporation, Alberta Power Limited, Shell Canada Limited, Unocal Canada Limited, Energy, Mines and Resources Canada, Alberta Oil Sands Technology and Research Authority, and other observers. Delta Projects Inc. provided coordination and promotional services to the Committee.

LNS Burner Steam Generator Demonstration

TRANSALTA RESOURCES INVESTMENT CORPORATION AND ESSO RESOURCES CANADA LIMITED, CALGARY[1]

The Low NO_x/SO_x Burner (LNSB) is a multi-stage, slagging-type combustor intended to control NO_x and SO_x simultaneously. It was developed by Rockwell International in the United States, but the technology is now owned by TransAlta Resources Investment Corporation of Calgary.

Earlier pilot-plant testing at 17.9 GJ/h (17 million BTU/hr.) confirmed the design concept for the LNSB. It indicated that the advanced combustion concepts of the LNSB can be used in a cost-effective manner to reduce SO_x emissions from the combustion of subbituminous coal by 70 per cent or more. Also, the device suppresses NO_x emissions to less than 100 parts per million (ppm), while achieving 100 per cent burnout of carbon monoxide and 95-99 per cent overall carbon burnout.

The LNSB fires pulverized coal in an entrained-flow system with staged combustion air. When there is insufficient calcium in the coal ash, more calcium is added to the coal, typically in the form of limestone. This is done to capture the sulphur present in the coal. In the combustion process, a large fraction of the coal is gasified, thus liberating the sulphur and creating the conditions for sulphur capture in a solid form. Also, the nitrogen gases from the coal, including NO_x, are converted to molecular nitrogen. The high temperatures in the process melt the coal ash for subsequent removal as molten slag.

Studies indicated that the capital cost of equipping coal-fired boilers with LNSBs should be significantly below the cost to obtain similar NO_x and SO_x control with state-of-the-art flue gas treatment systems. Also, operating costs should be greatly reduced. Furthermore, incorporation of a slag separator provides an opportunity for retrofit conversion of oil- or gas-fired boilers to coal firing.

Feasibility Study

During 1986/87, it was suggested that the LNSB might be installed on a gas-fired steam generator used to produce the steam needed for heavy oil recovery. Installation of the LNSB would permit coal to be used as fuel in place of natural gas.

Consequently, a study was initiated to determine the feasibility of installing a LNSB on an existing 52.7 GJ/h (50 million BTU/hr.) steam generator. It would burn low-ash, low-sulphur subbituminous coal.

The study resulted in the preparation of demonstration-scale and commercial-scale designs to allow the LNSB to be used with horizontal, once-through steam generators and Highvale coal, which averages 0.21 per cent sulphur.

The design included a target for SO_2 emissions of 129 ng/J (0.3 lb./million BTU), which is one-half the current level designated in Canadian regulations for emissions from either coal-fired or gas-fired burners. The target set for NO_x emissions was 86 ng/J (0.2 lb./million BTU). This is one-third the existing regulated level for coal-fired burners and equals the level established for gas-fired burners. The target for particulate emissions was a maximum of 43 ng/J (0.1 lb./million BTU).

[1]Funding was provided by TransAlta Resources Investment Corporation, Esso Resources Canada Limited, the Department of Western Economic Diversification, and the Alberta Office of Coal Research and Technology.

Demonstration Project

Beginning in 1988, TransAlta Resources Investment Corporation and Esso Resources Canada Limited initiated a demonstration of the LNSB at Esso's Mahihkan heavy oil extraction site near Cold Lake.

The project became known as LNS-CAP (Low NO_x/SO_x Coal Application Pilot). It was funded by a consortium of industry and government agencies comprising TransAlta Utilities Corporation, TransAlta Resources Investment Corporation, Esso Resources Canada Limited, Alberta Power Limited, Fording Coal Limited, Shell Canada Limited, Department of Western Economic Diversification and the Alberta Office of Coal Research and Technology.

The principal objectives of the project were to demonstrate:

- the ability to burn coal in an existing heavy oil recovery steam generator using the LNSB and a standalone 52.7 GJ/h (50 million BTU/hr.) steam generator;
- the capability of the LNSB to control SO_2 and NO_x emissions to satisfactory levels while firing Alberta subbituminous coals at a commercial scale under regular operating conditions;
- the reliability and durability of auxiliary systems operating with the burner and steam generator; and
- the capability of the LNSB to fire natural gas for a short duration in the event of a temporary interruption in coal availability.

It was also decided that a significant portion of the ash in coal must be removed from the LNSB as molten slag. This increases the possible applications for the burner, and removal rates above 60 per cent might allow gas- or oil-fired generators to be converted to coal.

Project engineering began in October 1988, and plant construction was completed in June 1990. The system was designed to provide 80 per cent quality steam at 15.5 MPa from feedwater containing high levels of dissolved solids--the same water used in Esso's commercial project near Cold Lake.

Operation and demonstration of the facility took place in four stages:

- start up on natural gas;
- start up on coal;
- performance evaluation; and
- extended system demonstration.

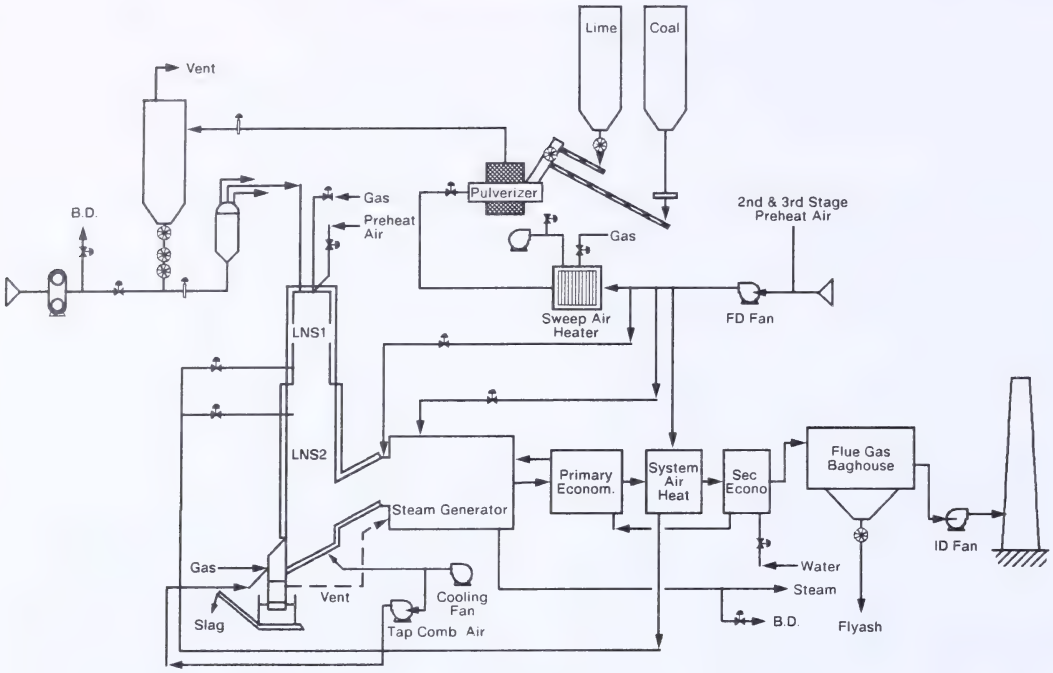
Altogether, 17 test runs were carried out in the four phases.

All individual components, instruments and analysers were checked during test runs with natural gas; the coal start-up phase began in July 1990. Although this phase was expected to last only two months, it had to be extended to eight months to allow correction of several deficiencies in the mechanical systems and operating procedures. Plugging problems involving the slag tap were particularly difficult to solve.

Eventually, a new, larger slag tap was designed and installed. It overcame the plugging problem.

It became apparent during the system performance phase that the refractory lining inside the combustor was being eroded by the flowing slag. After trying several types of refractory material, one was selected to replace the original material. This resulted in satisfactory slagging performance, and refractory erosion was reduced significantly.

LNS-CAP Process Flow Diagram



In the final phase, which was intended to demonstrate the reliability of the burner and range of conditions over which it could operate, the burner operated consistently, but ash build-up in the radiant section of the steam generator prevented sustained operation. This problem was brought under some control and a continuous run lasting 148 hours was completed. In this run, the SO_2 capture was less than expected. Since it was apparent that a longer period of continuous operation would incur significant costs for needed modifications to the radiant section of the generator, the project was terminated at this point because the participants could not justify the added expense.

By the end of the test program, the LNSB and its instrumentation operated reliably and consistently. The emissions of NO_x were generally at or below the target, and at times were maintained at 64 ng/J (0.15 lb./million BTU). In some cases, SO_2 emissions were kept below the target level, and 50 per cent sulphur capture was achieved, but the results were inconsistent. On the other hand, carbon burnout was consistently above 99 per cent. This compares with 95 to 98 per cent burnout in conventional coal-fired combustors. Although the plant was not operated long enough to carry out stack surveys of particulates, measurements of stack opacity showed no change when the fuel was switched from natural gas to coal. Compared with a target slag removal rate of 60 per cent, the actual results ranged from 50 to 65 per cent.

After the coal-combustion process had stabilized, steam quality from the generator was raised from 50 per cent to values ranging from 60 to 70 per cent.

Based on these results, and considering the potential for marketing this technology under current economic conditions, as well as the relative prices of natural gas and coal, it was concluded that proceeding to a commercial-scale demonstration could not be justified at this time.

Publication

TransAlta Resources Investment Corporation. 1992. LNS-CAP Project. Demonstration of Low NO_x/SO_x Burner and Coal Use In Heavy Oil Recovery. Volume I. Executive Summary. Prepared for Alberta Office of Coal Research and Technology, Western Economic Diversification Canada and The Operations Review Committee.

Western Canadian Low-Sulphur Coal to Ontario Program

Since the mid-1980s, the potential social and economic benefits of using increased amounts of western Canadian coal in Ontario have been investigated and described by various federal/provincial task forces representing the federal government and the governments of Ontario and the western coal-producing provinces. The most recent of these groups, called the Action Committee on Western Canadian Low-Sulphur Coal to Ontario, comprises the Deputy Prime Minister and the premiers of British Columbia, Alberta, Saskatchewan and Ontario. In 1987, this committee created an Intergovernmental Secretariat that consulted with coal producers, transporters and users to develop possible technological, regulatory and policy options which could lower the delivered cost of western Canadian coal in Ontario.

In its November 1987 report to the Action Committee, the Secretariat identified 14 research and development initiatives within four broad categories that should be pursued.

The categories are as follows:

- Mine Production Improvements;
- Coal Product Improvements;
- Transportation Improvements; and
- Fiscal and Regulatory Improvements.

While each of these initiatives will require cooperation among the member governments and industry, the Alberta government agreed to take the lead in implementing the following three initiatives:

- Underground Thick-Seam Extraction Using the Room and Pillar System of Mining;
- Ash Reduction, Refuse Reprocessing and Fines Processing; and
- Coal-Oil Mixture Slurry Transportation Concept.

Some of these activities and those led by other governments or The Coal Association of Canada are directed by management committees comprising representatives of interested governments and industries.

The program includes studies of the impact of taxes and regulatory costs on coal transportation by railways and pipelines, and on coal producers.

Thick-Seam Extraction and Continuous Haulage Mining Demonstration

SMOKY RIVER COAL LIMITED, GRANDE CACHE

Considerable reserves of high-quality thermal and metallurgical coal are present in seams more than 3.7 m thick in western Canadian coalmines. Many of these seams are steeply inclined, however, and difficult to mine using the current room-and-pillar extraction methods. Most mechanized coalmining machines cannot reach heights above 3.5 m, leaving large quantities of coal unmined.

Recent developments in machinery design and mining systems, however, suggest that seams up to 6.1 m thick can be mined successfully by consistently removing more of the coal that comprises the floor of the mined area. This could permit recovery rates that are up to 15 per cent higher than current rates. Furthermore, the current practice of using a continuous mining machine and then shuttle cars to transport mined coal from the active face to a distant conveyor could be improved. A 21 per cent loss in the optimum operating time of the continuous miner results while it waits for shuttle cars to deliver their loads and make the return trip.

Consequently, a project was initiated in 1989 at the Smoky River coalmine to evaluate new methods of mining coal at greater heights, and to assess a mobile roof support system to bolt the 6.1-m high roof in the underground mine. These were accompanied by the use of a mobile conveyor capable of continuously removing the mined coal. This conveyor, which is 183 m long and can negotiate 90° turns, is designed to transport 12 tonnes of coal a minute. It was anticipated that the mobile conveyor would be 30 per cent more productive than the shuttle-car system.

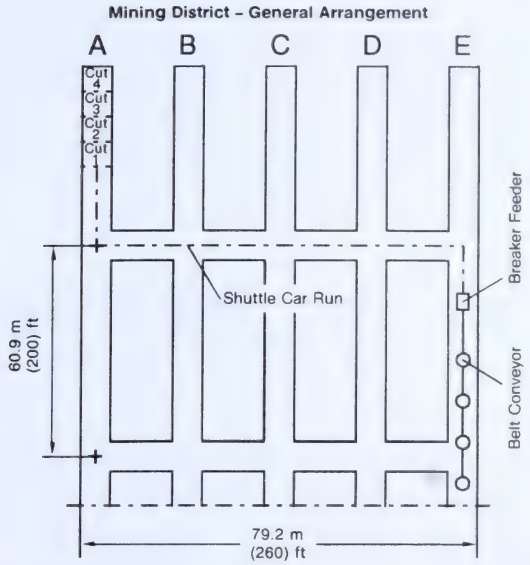
Also, a strata-monitoring program was implemented to determine the effects, if any, of the higher roof heights on the behaviour of the coal-seam and surrounding overburden. Furthermore, the deposit that was mined during this project was deeper than any encountered at this mine, and it was observed that the geomechanical properties predicted by existing mathematical models diverged increasingly from actual measurements as the mine was driven deeper. The accuracy of strata-control procedures is important in striking a balance between optimal extraction of coal and the provision of adequate pillar mass to support the roofs of mined areas.

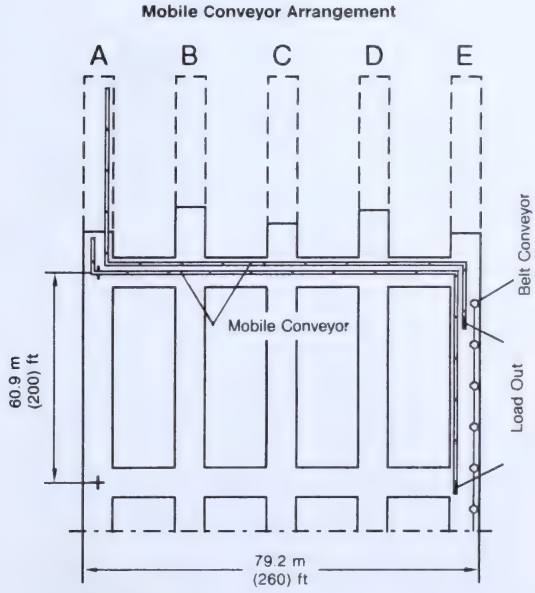
The major elements of the monitoring program were as follows:

- measuring roof and floor movement, including roof separation, roof depression and floor heave;
- measuring side (rib) movement, including side travel movement; and
- monitoring pillar behaviour, including pillar squeezing and roof-to-floor pressure.

In 1990, a Fletcher dual-head roof and side bolter was used successfully to support the roof and sides of extracted coal-seams. The presence of sheared coal, and the limited reach of the existing continuous miner, however, prevented using the full height capabilities of the equipment. Heights of only 3.7 m to 4.3 m could be excavated safely, but the strata-monitoring program showed that mining to the full height was safe. Achieving this would require the use of a continuous miner having a 6.1-m reach.

Problems with the electrical and mechanical systems of the Kloeckner-Becorit mobile conveyor delayed its use for most of 1989, but during the first half of 1990, the conveyor transported increasing quantities of coal, and on one occasion moved 800 tonnes in 4.5 hours. This represented a 35 per cent improvement over the use of shuttle cars.





During the second half of 1990, several problems with the mobile conveyor arose. Numerous electrical and mechanical breakdowns occurred, causing inconsistent performance. In addition, the machine could not properly negotiate soft floors or gradients in the seam. Although the conveyor could travel in a straight line over level surfaces, it tended to move sideways in a snake-like fashion whenever it encountered an inclined portion of the floor. After consultation with the equipment manufacturer, it was decided to reduce the length of the mobile conveyor to 131 m.

Several modifications were made to the conveyor and tests were carried out during 1991. Unfortunately, the difficulties could not be corrected and the conveyor was taken out of service in February 1992.

Although the mobile conveyor aspect of the demonstration was regarded as a failure, the company gained considerable knowledge from the strata-monitoring program. This information is now used routinely in all mining activities. Also, the roof and side bolter achieved its objectives. Thus, an ability to remove mined coal quickly was the only objective not met, and the company is currently investigating the use of larger shuttle cars to achieve this.

The project was financed by Smoky River Coal Limited, the Department of Western Economic Diversification, and the Alberta Office of Coal Research and Technology.

Publications

Associated Mining Consultants Limited. 1989. Geotechnical Monitoring Thick Seam Room-and-Pillar Demonstration Project. A report to Smoky River Coal Limited.

Kulach, J. 1989. Thick Seam Underground Mining Demonstration Project. Ground Control Monitoring and Instrumentation Plan. Smoky River Coal Limited.

Kulach, J. and H.H. Sandkuhler. 1991. Thick Seam Mining Demonstration Project Research Aspects. Alberta Coal Research Contractors' Conference, Calgary, October 30. Smoky River Coal Limited.

Kulach, J. and H.H. Sandkuhler. 1990. Continuous Transport of Materials, Underground Flexible Conveyor System. CIM 92nd Annual General Meeting, Ottawa, Ontario.

Kulach, J. and H.H. Sandkuhler. 1989. Thick Seam Underground Mining Demonstration Project. CIM Conference, Calgary, Alberta.

Smoky River Coal Limited. 1991a. Thick Seam Underground Mining Demonstration Project. Final Report for Phase I.

Smoky River Coal Limited. 1991b. Thick Seam Underground Mining Demonstration Project. Annual Report 1990.

Smoky River Coal Limited. 1990. Thick Seam Underground Mining Demonstration Project. Annual Report 1989.

Coal/Oil Upgrader - Phase II

FORDING COAL LIMITED (CALGARY) AND OTHER PARTICIPANTS[1]

The vendor-testing program recommended at the conclusion of the Coal/Oil Upgrader project was begun this year, with financial support from the Western Canadian Low-Sulphur Coal to Ontario Program.

The principal objective is to use the equipment made by various manufacturers to try dewatering or de-oiling the agglomerates produced from Genesee subbituminous coal and Elk Point heavy oil.

Thus far, eight tonnes of agglomerates, produced at the Alberta Research Council, were shipped to Allis Minerals in the U.S.A. for preliminary testing in various pyro-processing equipment. When the results of this work are known, a pilot plant will be constructed and operated to demonstrate the coal/oil upgrading process at a larger scale.

[1]In addition to Fording Coal Limited and the Office, PanCanadian Petroleum Limited and the Department of Western Economic Diversification are providing funding for this project.

Comprehensive Coal Preparation Plant Performance Evaluations

THE COAL ASSOCIATION OF CANADA, CALGARY[2]

Studies in the U.S.A. and Australia have shown that the clean-coal yield of many coal preparation plants can be improved by one to five per cent through optimizing a plant's performance. Experience with one western Canadian coal company showed that an overall improvement of five per cent was possible. This amounts to an additional 180 000 tonnes of coal a year, or revenues of approximately $9 million.

Because these improvements began with a comprehensive evaluation of individual preparation plants, this project was initiated with the following objectives:

- to reduce the cost of producing merchantable coal by improving the recovery of clean coal;
- to reduce the environmental effects resulting from coal cleaning by reducing the volume of tailings that must be stored in ponds;

[2]The project is being funded by the Office, the Department of Western Economic Diversification and individual coal companies. Participating from Alberta are Crows Nest Resources Limited, Esso Resources Canada Limited, Luscar Ltd., Gregg River Resources Ltd. and Smoky River Coal Limited.

- to increase the overall recovery of coal;
- to establish baseline information on coal preparation plant performance in Canada; and
- to increase business opportunities for consultants and research organizations by defining the work needed to optimize plant operation.

Under direction of The Coal Association of Canada, staff of CANMET's Western Research Laboratory at Devon have begun to sample coal preparation plants in Alberta. The collected samples are analysed for ash, moisture, solids content and float-sink, and some may be tested for heat value. Based on these analyses and material balances, the performance of each plant is evaluated. Those plants that are performing at or above their design specification are rated as successful. Those that are operating below their design capabilities are examined closely, and recommendations are made for changes to the operation.

The project is intended to take place over three years. During this time, 14 coal preparation plant audits will be undertaken, 10 for Alberta plants and four for plants in B.C. Thus far, commitments to participate have been received from six Alberta coalmining companies.

Tailings Reclamation

LUSCAR STERCO (1977) LTD.(EDSON) AND LUSCAR LTD. (OBED)

All coal preparation plants generate coal refuse known as tailings. Depending on the type of coal being mined, as well as the preparation plant yield and the amount of clay present in the tailings, the disposal of tailings into holding ponds can represent a significant portion of preparation plant operating costs.

Various methods for dewatering slurries containing tailings have been tried, including mechanical dewatering using filter presses. In this project, however, an alternative method was tried. It involved dewatering an existing tailings pond and experimenting with various methods for stabilizing and reclaiming it. It was reasoned that if this were practical, slurry dewatering might not be necessary and tailings ponds could be converted to a more useful purpose than for waste storage.

For this concept to be successful in practice, it was necessary to determine how much topsoil and subsoil were needed to reclaim the tailings pond in an environmentally sustainable manner.

Initially, greenhouse tests were carried out at the Alberta Research Council to identify plant species capable of growth in tailings ponds at the Coal Valley and Obed Mountain mines of Luscar-Sterco (1977) Ltd. These botanical tests were carried out on tailings alone, soil alone, soil over tailings, and a 1:1 mixture of soil and tailings.

Then, a 1.2 ha parcel of a drained tailings pond at the Coal Valley mine was prepared for seeding. The plot was divided into four sections: tailings only; tailings plus 15-cm or 30-cm soil caps; and a 15-cm soil cap above a 105-cm layer of spoil material that was placed over the tailings. These sections were seeded with mixtures of reed canary grass, alfalfa, timothy, clover and redtop.

Meanwhile, geotechnical assessment of the site began, with the work carried out by Thurber Consultants Ltd. It included installation of piezometers and settlement plates, as well as performing vane shear and cone penetrometer tests.

More than one year after the seed mixtures were sown, plant tissue and growth analyses were carried out. These initial biological tests showed that the tailings material is biologically non-toxic and is capable of supporting plant growth under most conditions. Also, plant growth was improved somewhat in the test sections that used a soil cap. The extent of this improvement was investigated for another year.

After the second year of growth, biological monitoring of the forage cover that had been established a year earlier was carried out, and certain chemical properties of the waste material were measured. The biological and chemical results were compared with baseline conditions that had been measured in 1988.

It was found that the greatest crop yield occurred on the section capped with a 120-cm layer of topsoil, but the yields from the other test sections, including the waste material alone, were more than adequate. Furthermore, the uptake of chemical elements by the crops grown on the waste material alone was similar to that observed for the test sections having a topsoil cover. Some slight changes in the chemical properties of the waste material were noted, but the changes tended to favour improved growing conditions.

Financial support for this project was provided by Luscar Sterco (1977) Ltd., Luscar Ltd., the Department of Western Economic Diversification, and the Alberta Office of Coal Research and Technology.

Publication

Macyk, T.M., F.I Nikiforuk and Z.W. Widtman. 1991. Characterization and Reclamation of Coal Tailing Materials. Alberta Research Council.

Feasibility Study - IGCC Power Plant

THE COAL ASSOCIATION OF CANADA, CALGARY

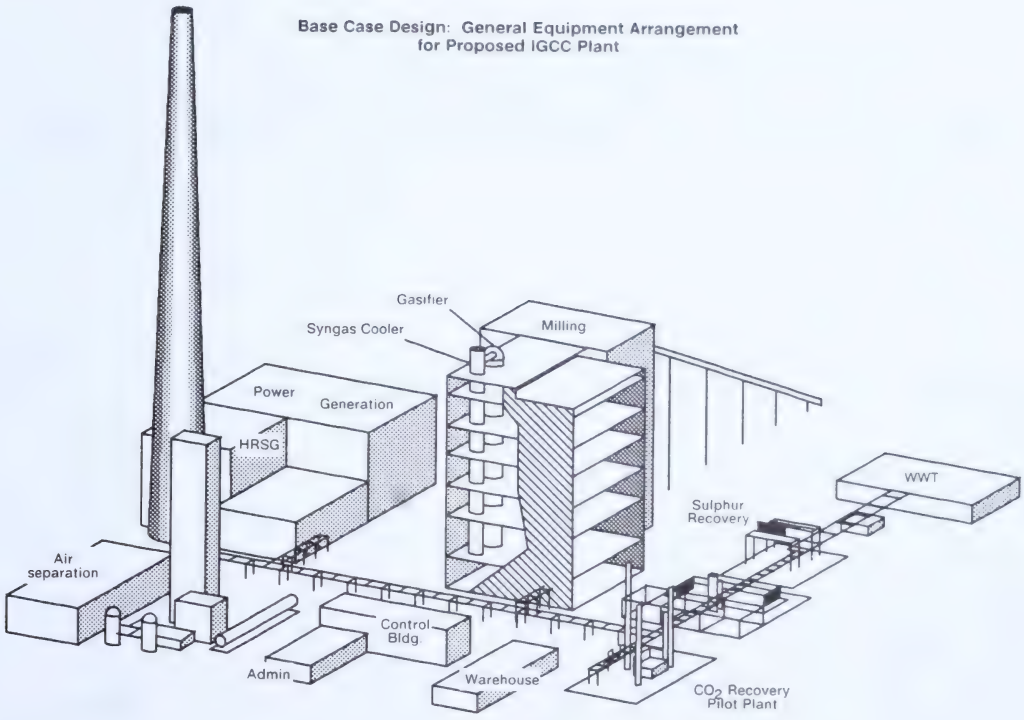
The Coal Association of Canada was the lead agency in a project funded jointly by several governments and industry[1]. The objective was to undertake a feasibility study of an Integrated Gasification Combined Cycle (IGCC) power plant to be located in western Canada. One requirement was that the chosen technology must be capable of recovering carbon dioxide.

The feasibility study was subcontracted to Bechtel Canada Inc. This firm prepared a base-case plant design in sufficient detail to provide a capital cost estimate that is accurate to within plus or minus 20 per cent. Also, a preliminary environmental study was carried out by Beak Associates Consulting Ltd.

The Bechtel design includes Shell gasifier technology, a conventional air separation unit and a General Electric 7F gas turbine. The gasification plant is sized to provide the fuel required by the gas turbine at 6°C, and the plant is capable of using approximately 2 700 tonnes of coal a year and producing a net output of up to 244 MW of electrical power. If built, the plant would be one of the world's largest IGCC operations.

The design is meant to achieve an overall energy efficiency of 40.4 per cent, which is superior to that of most pulverized coal-fired power plants. It would produce power at a levelized cost of $0.06/kWh, compared with approximately $0.04/kWh for a new pulverized coal-fired power plant.

[1]The study was supported by: The Canadian Electrical Association, Cape Breton Development Corporation, Nova Scotia Power Corporation, SaskPower Corporation, Crows Nest Resources Ltd., Manalta Coal Ltd., Fording Coal Limited, Luscar Limited, TransAlta Utilities Corporation, Edmonton Power Limited, Westar Mining Ltd., Alberta Power Limited, Ontario Hydro, and the governments of British Columbia, Alberta, Saskatchewan, Ontario and Canada. The study was administered by The Coal Association of Canada.



The design allows 99 per cent recovery of potential SO_2 emissions, and the plant NO_x emissions are limited to 51 ng/J (0.12 lb./million BTU). This is one-fifth the level allowed in the current standards, and developing designs have the potential to reduce NO_x emissions below 12 ng/J (0.03 lb./million BTU). The higher energy efficiency of the design relative to power plants fired by pulverized coal means CO_2 emissions should be reduced as well, perhaps by as much as 15 to 20 per cent. Solid waste is limited to coal ash in the form of slag or fly slag, which leaves the process as a vitreous substance that is impervious to leaching by water. The plant is also designed so that no liquid wastes will be discharged. Instead, all process water, boiler blowdown and effluents are reused.

Capital costs were estimated to be $595 million, or $2 440/kW. The estimated operating costs were $29.2 million a year, assuming an 80 per cent capacity factor and the use of subbituminous coal priced at $12/tonne. These costs would rise to $34.4 million if the plant is operated at full capacity.

It was estimated that it would take four years to engineer, construct and commission the plant.

Three likely sites for a plant are being considered. They are: the Keephills plant of TransAlta Utilities; Edmonton Power's Genesee plant; and Saskatchewan Power's Shand II plant.

Currently, financial support is being sought to proceed with a detailed design of a plant.

Publication

Geosits, R.F., L.A. Schmoe, J.H. Westsik and B.W. Raymond. 1991. The Coal Association of Canada IGCC Feasibility Study Update. Presented at the 1991 Fall Meeting, Thermal and Nuclear Power Section of the Canadian Electrical Association.

Project Expenditures

Table 1: Funding Contributions to Approved Projects by Year ($)

PROJECT TITLE	1977-87	1988/89	1989/90	1990/91	1991/92	Projected 1992/93	TOTAL
A/CERRF-FUNDED PROJECTS							
A/CERRF - COAL RESEARCH							
Resource Evaluation							
Creep Characteristics of Coal	16 459	-	-	-	-	-	16 459
Reflective Seismic Investigation of Western Canadian Coalfields	3 564	-	-	-	-	-	3 564
VLF Geophysical Methods in Coal Exploration	14 846	-	-	-	-	-	14 846
Geophysical Instrumentation	69 470	-	-	-	-	-	69 470
Geotechnical Properties of Overburden	71 501	-	-	-	-	-	71 501
Surface Geophysical Coal Exploration	333 468	-	-	-	-	-	333 468
3-D Structural Geometry	53 000	-	-	-	-	-	53 000
In-Seam Coal Characterization	236 824	-	-	-	-	-	236 824
Seismic Modelling of Shallow Coalfields	32 443	37 096	159	-	-	-	69 698
Downhole Geophysical Characterization of Overburden	74 766	104 500	-	-	-	-	179 266
Surface Geophysical Techniques for Foothills and Mountain Coalfield Exploration	-	73 835	47 094	146 842	-	-	267 771
Coal-Bed Methane: An Alberta Opportunity	-	-	-	40 000	-	-	40 000
SUBTOTAL: Resource Evaluation	906 341	215 431	47 253	186 842	0	0	1 355 867
Mining							
Support Design for Underground Cavities in Weak Rock	1 350	-	-	-	-	-	1 350
Coal Mining Research	1 955 562	-	-	-	-	-	1 955 562
Coal Mining in 2035	78 682	-	-	-	-	-	78 682
Triaxial Test Development	103 503	-	-	-	-	-	103 503
Ground Movements in Coal Mines	25 500	-	-	-	-	-	25 500
Mining 2035 Workshop	25 226	-	-	-	-	-	25 226
Robotics for Mine Control	96 178	-	-	-	-	-	96 178
Non-Cable Vehicle Guidance	133 455	-	-	-	-	-	133 455
Lasers in Coal Mining	50 954	-	-	-	-	-	50 954
Geostatistics	40 958	-	-	-	-	-	40 958
Footwall Anchoring	139 099	-	-	-	-	-	139 099

PROJECT TITLE	1977-87	1988/89	1989/90	1990/91	1991/92	Projected 1992/93	TOTAL
Time-Dependent Behaviour of Coal Measure Rocks	35 033	4 967	-	-	-	-	40 000
Deformation and Progressive Failure of Open-Pit Highwalls	71 978	12 724	-	-	-	-	84 702
Automated Machine Control for Optimized Mining (AMCOM)	-	197 222	-	-	-	-	197 222
Dragline Operations Monitor	-	40 225	-	-	-	-	40 225
SUBTOTAL: Mining	2 757 478	255 138	0	0	0	0	3 012 616
Preparation and Upgrading							
Beneficiation of Coal by Agglomeration in Pipelines	22 220	-	-	-	-	-	22 220
Coal Preparation Research	4 692 489	-	-	-	-	-	4 692 489
Coal Comminution	54 466	-	-	-	-	-	54 466
Numerical Analysis of Process Yield Losses	75 795	-	-	-	-	-	75 795
Advanced Processes for Low-Rank Coal	79 392	-	-	-	-	-	79 392
Properties of Thermally Dried Coals	144 459	-	-	-	-	-	144 459
Stabilization of Dried Coal	37 423	-	-	-	-	-	37 423
Agglomeration of Low-Rank Alberta Thermal Coals	136 754	(5 969)	-	-	-	-	130 785
Agglomeration for Beneficiation	49 772	-	-	-	-	-	49 772
Preparation and Upgrading Assistance to AOCRT	42 000	-	-	-	-	-	42 000
Moisture and Ash On-Stream Analyser	26 553	-	-	-	-	-	26 553
Recovery of Coal from Tailings	82 231	-	-	-	-	-	82 231
Fine Coal Technical Assistance	2 308	-	-	-	-	-	2 308
Froth Flotation Study at Coal Valley	29 237	-	-	-	-	-	29 237
Washery Optimization	220 978	-	-	-	-	-	220 978
Coal Beneficiation Process	883 978	23 461	-	-	-	-	907 439
Agglomeration of Coking Coal	90 000	-	-	-	-	-	90 000
Westcoal Separator Phase II	-	24 898	-	-	-	-	24 898
Coal Production Program Planning	-	36 750	6 484	-	-	-	43 234
Electrocoagulation	-	15 046	-	33 333	-	-	48 379
Coal Agglomeration Process Development	35 000	35 000	17 500	38 500	-	-	126 000

PROJECT TITLE	1977-87	1988/89	1989/90	1990/91	1991/92	Projected 1992/93	TOTAL
Particle Distribution in Slurry Flow Through Tees and Manifolds	-	53 222	43 570	16 178	-	-	112 970
Coal/Oil Upgrader	-	-	-	93 500	-	-	93 500
SUBTOTAL: Preparation and Upgrading	6 705 055	182 408	67 554	181 511	0	0	7 136 528
Combustion							
Combustion of Agglomerated Coal	33 336	-	-	-	-	-	33 336
Combustion Process Research	150 215	-	-	-	-	-	150 215
Combustion Characteristics of Alberta Coals	188 970	-	-	-	-	-	188 970
Combustibility of Agglomerates	14 156	-	-	-	-	-	14 156
Combustion Program Planning	76 604	-	-	-	-	-	76 604
Influence of Porosity on Combustion	84 000	-	-	-	-	-	84 000
Causes of Spontaneous Combustion of Western Canadian Coals	98 436	705	-	-	-	-	99 141
Combustibility of Upgraded Alberta Coals	115 000	-	-	-	-	-	115 000
Evaluation of Blending on Combustibility	36 000	-	-	-	-	-	36 000
Prediction of Coal Combustibility	147 416	-	-	-	-	-	147 416
Combustion Properties of Alberta Coals and Chars	-	150 000	-	-	-	-	150 000
Spontaneous Combustion of Thermally Treated Coals	-	25 503	-	-	-	-	25 503
International Energy Agency Basic Coal Combustion Science	432 695	32 869	-	-	-	-	465 564
A Thermodynamic Model for Spontaneous Combustion of Coal	-	54 567	40 918	-	-	-	95 485
Travel Grant to Study Sources of Ash in Controlled Conditions at IJumuiden	-	-	5 231	3 044	-	-	8 275
Program Extension to IEA Annex II Basic Coal Combustion Science	-	-	94 640	102 383	210 944	-	407 967
Technology Transfer of IEA Coal Combustion Sciences Research	-	38 808	39 227	40 519	44 212	-	162 766
Ash Properties of Alberta Coals	-	-	49 962	148 638	-	-	198 600
SUBTOTAL: Combustion	1 376 828	302 452	229 978	294 584	255 156	0	2 458 998
Liquefaction/Co-processing							
Coal Liquefaction Study	151 864	-	-	-	-	-	151 864
Coal Liquefaction Feasibility Study	90 553	-	-	-	-	-	90 553

PROJECT TITLE	1977-87	1988/89	1989/90	1990/91	1991/92	Projected 1992/93	TOTAL
PYROSOL Process Review	7 006	-	-	-	-	-	7 006
Liquefaction Process Improvement	51 059	-	-	-	-	-	51 059
ENR/ARC Coal Conversion Research	14 342 349	-	-	-	-	-	14 342 349
New Liquefaction Processes	230 949	-	-	-	-	-	230 949
Preliminary Economic Evaluation of a Multistage Coal/Heavy Oil Co-processing Concept and Development of a Simple Process Evaluation	77 791	-	-	-	-	-	77 791
Isotopic Analysis of Co-processing Schemes	74 000	-	-	-	-	-	74 000
Secondary Upgrading	182 671	329	-	-	-	-	183 000
Functional Group Analysis of Coal Liquids	91 000	-	-	-	-	-	91 000
Chemistry of Coal Liquefaction	508 904	5 753	-	-	-	-	514 657
Secondary Upgrading of Co-processing Products	-	172 000	-	-	-	-	172 000
Supercritial Gas Extraction of Coal	73 205	9 071	-	-	-	-	82 276
Liquefaction of Coal with Natural Gas	29 404	6 346	-	-	-	-	35 750
Hydroprocessing of Coal-Derived Liquids	61 816	24 205	19 379	-	-	-	105 400
Isotopic Studies of Coal/Bitumen Co-processing	77 784	43 508	(566)	-	-	-	120 726
Molecular Interactions Between Heavy Oil and Coal Species During Co-processing	-	48 464	54 813	3 123	-	-	106 400
Product and Process Characterization	-	218 156	86 864	71 706	-	-	376 726
Co-processing Process Development	2 886 111	630 249	643 763	257 159	-	-	4 417 282
Combined Processing of Coal, Heavy Oil and Natural Gas	-	-	18 783	41 217	-	-	60 000
Specialty Chemicals from Coal-Derived Liquids	-	-	79 900	129 544	-	-	209 444
Process Development for Carbon Fibres from Coal-Derived Liquids	-	-	-	-	97 306	-	97 306
Co-processing of Coal with Molten Halide Catalysts	-	-	40 000	30 000	-	-	70 000
Co-processing of Coal and Heavy Oil in Alberta, Phase II	-	-	-	50 000	-	-	50 000
Coal/Oil Co-processing Using a Counterflow Reactor	-	-	-	296 369	-	-	296 369
SUBTOTAL: Liquefaction/Co-processing	**18 936 466**	**1 158 081**	**942 936**	**879 118**	**97 306**	**0**	**22 013 907**

PROJECT TITLE	1977-87	1988/89	1989/90	1990/91	1991/92	Projected 1992/93	TOTAL
Gasification							
Gasification of Western Canadian Coals	38 500	-	-	-	-	-	38 500
Fluidized Bed Gasification of Highvale Coal	64 201	-	-	-	-	-	64 201
Gasification Process Research	84 361	(401)	-	-	-	-	83 960
Gasification Properties of Alberta Coals	164 957	-	-	-	-	-	164 957
Gasification Laboratory Facilities	160 000	-	-	-	-	-	160 000
Corrosion in Gasification Systems	50 871	460	-	-	-	-	51 331
Gasification Characteristics of Alberta Coals	185 316	59	-	-	-	-	185 375
Devolatilization Properties of Alberta Coals	-	150 000	28 530	-	-	-	178 530
IGCC Utility Applications	-	-	25 000	-	-	-	25 000
Canada/Japan Collaboration in Coal Gasification Research	-	-	-	38 664	15 993	-	54 657
Gasification Properties of Alberta Coals	-	190 000	154 000	208 800	-	-	552 800
SUBTOTAL: Gasification	**748 206**	**340 118**	**207 530**	**247 464**	**15 993**	**0**	**1 559 311**
Transportation							
Coal Slurry Pipeline Research	287 953	-	-	-	-	-	287 953
Coal Market Access Model	69 846	4 125	-	-	-	-	73 971
Coal-Oil Slurry Pipelining	204 331	455 578	-	-	-	-	659 909
Coal Slurry Technology	25 576	22 411	173 566	62 671	-	-	284 224
SUBTOTAL: Transportation	**587 706**	**482 114**	**173 566**	**62 671**	**0**	**0**	**1 306 057**
Environment							
Low NO_xSO_x Burner	50 028	-	-	-	-	-	50 028
Coal Conversion Waste-Water Treatment	64 000	-	-	-	-	-	64 000
Sorbent Injection Study	-	15 000	-	-	-	-	15 000
A State-of-the-Art Review on CO_2 Separation/Disposal Technologies	-	-	-	12 500	-	-	12 500
Gypsum as an Alternate Flocculent in the Treatment of Coal Mine Effluent Water	-	-	-	-	25 240	-	25 240
SUBTOTAL: Environment	**114 028**	**15 000**	**0**	**12 500**	**25 240**	**0**	**166 768**
Markets							
Conversion from Oil to Coal-Water Fuels	35 376	430	-	-	-	-	35 806

PROJECT TITLE	1977-87	1988/89	1989/90	1990/91	1991/92	Projected 1992/93	TOTAL
Production of Activated Carbon	-	759	-	-	-	-	759
Activated Carbon from Coal	89 735	10 265	-	-	-	-	100 000
SUBTOTAL: Markets	125 111	11 454	0	0	0	0	136 565
Enhanced Oil Recovery							
Fuel Options for Enhanced Oil Recovery	15 000	-	-		-	-	15 000
Coal Use in Enhanced Oil Recovery	31 772	-	-	-	-	-	31 772
Coal-Fired Steam Injection Boiler	28 619	110 205	-	-	-	-	138 824
Application of the LNS Burner to an Oil Field Steam Generator	-	22 460	-	-	-	-	22 460
Economics of Coal Use for Heavy Oil Recovery	-	-	50 000	-	-	-	50 000
Coal/Condensate Slurry Pipelining	-	-	251 603	80 740	-	-	332 343
LNS Burner Steam Generator Demonstration	-	292 266	1 964 000	506 600	300 000	-	3 062 866
Coal/Condensate Slurry Pripeline Engineering Cost Study	-	-	-	25 311	-	-	25 311
SUBTOTAL: Enhanced Oil Recovery	75 391	424 931	2 265 603	612 651	300 000	0	3 678 576
Other							
Coal Technology Information Centre	571 120	-	-	-	-	-	571 120
CTIC Review	16 997	-	-	-	-	-	16 997
Data Gathering for Research Planning	51 996	-	-	-	-	-	51 996
Electrolysis of Coal Slurries	113 000	-	-	-	-	-	113 000
Sulphur Isotope Studies of Coal	25 119	38 081	-	-	-	-	63 200
Electrolysis of Coal Slurries II	-	48 497	11 503	-	-	-	60 000
Distributed Chemical and Physical Properties of Coal	8 973	30 450	12 538	-	-	-	51 961
Magnetic and Electric Properties of Alberta Coals	40 397	69 053	-	-	-	-	109 450
Distribution of Oxygen Forms in Western Canadian Low-Rank Coals	-	21 068	18 932	-	-	-	40 000
SUBTOTAL: Other	827 602	207 149	42 973	0	0	0	1 077 724
SUBTOTAL: A/CERRF - COAL RESEARCH	33 160 212	3 594 276	3 977 393	2 477 341	692 177	0	43 901 399

PROJECT TITLE	1977-87	1988/89	1989/90	1990/91	1991/92	Projected 1992/93	TOTAL
A/CERRF - ALBERTA UNIVERSITIES PROGRAM							
Analysis of Coal-Bearing Strata Near Cadomin	20 00	-	-	-	-	-	20 000
Reflective Seismic Investigation of Western Canadian Coalfields	563 428	-	-	-	-	-	53 428
Support Design for Underground Cavities in Weak Rock	130 804	-	-	-	-	-	130 804
Coal Ash Monitoring System	71 633	-	-	-	-	-	71 633
Automedium Cyclones	95 711	-	-	-	-	-	95 711
Beneficiation of Coal by Agglomeration in Pipelines	185 414	-	-	-	-	-	185 414
Hydroprocessing of Coal-Based Liquids	84 936	-	-	-	-	-	84 936
Supercritical Gas Extraction of Coal	67 292	-	-	-	-	-	67 292
Coal Conversion Waste-Water Treatment	87 890	-	-	-	-	-	87 890
Production of Activated Carbon	39 441	-	-	-	-	-	39 441
SUBTOTAL: A/CERRF - ALBERTA UNIVERSITIES PROGRAM	836 549	0	0	0	0	0	836 549
DEPARTMENT-FUNDED PROJECTS							
Alberta Coal Geology Project	700 239	499 761	410 071	37 411	-	12 518	1 660 000
Smoky DENSECOAL Combustion Tests	9 560	-	-	-	-	-	9 560
Impact of Quality on the Utilization Potential of Alberta Coals and Its Effect on the Environment	-	-	-	-	55 982	19 875	75 857
Synthetic Fuels Program	48 220	-	-	-	-	-	48 220
Economic Evaluation of Coal/Oil Co-processing	48 117	-	-	-	-	-	48 117
Counterflow Reactor Development, Phase II	-	-	-	-	128 406	-	128 406
Coal Research Contractors' Conference	-	-	-	-	8 397	10 000	18 397
Economics of Coal Gasification	10 045	-	-	-	-	-	10 045
Corrosion in Gasification Systems	43 069	-	-	-	-	-	43 069
Canadian Coal Gasification Project (CANMET/ARC)	-	-	-	-	210 000	150 000	360 000
Coal/Oil/Natural Gas Transportation System	25 000	-	-	-	-	-	25 000

PROJECT TITLE	1977-87	1988/89	1989/90	1990/91	1991/92	Projected 1992/93	TOTAL
Coal for Use in Enhanced Oil Recovery: Emission Control Technhology	-	14 625	-	-	-		14 625
CO_2 Disposal/Utilization Workshop	-	-	-	-	5 084	916	6 000
Development of Sport Fisheries in Lakes Created by Coalmining Operations in the Eastern Slopes	-	-	-	-	21 740	24 159	45 899
CO_2 Disposal Study - Phase II	-	-	-	-	29 611	-	29 611
Greenhouse Gases R&D Program	-	-	-	-	162 000	9 180	171 180
SUBTOTAL: DEPARTMENT-FUNDED PROJECTS	884 250	514 386	410 071	37 411	621 220	225 732	2 693 070
TOTAL ALBERTA COAL RESEARCH	34 881 011	4 108 662	4 387 464	2 514 752	1 313 397	225 732	47 431 018
WESTERN CANADIAN LOW-SULPHUR COAL TO ONTARIO PROGRAM							
Thick-Seam Extraction and Continuous Haulage Mining Demonstration	-	291 773	1 746 540	353 655	350 391	-	2 742 359
HYDROSIZER for Fine Coal Recovery from Tailings	-	21 000	-	-	-	-	21 000
Testing of ARCOFLUX 130	-	5 040	-	-	-	-	5 040
Air-Sparged Hydrocyclone	-	41 577	86 354	-	-	-	127 931
On-Line Coal Analysers	-	-	83 733	-	-	-	83 733
Tailings Reclamation	-	3 649	25 182	8 380	6 560	-	43 771
Developing a Practical Model for the Compound Water Cyclone	-	-	-	56 288	-	-	56 288
Thermal Drying of Western Canadian Low-Rank Coals	-	-	-	9 283	-	-	9 283
Coal/Oil Upgrader - Phase II	-	-	-	-	306 000	964 000	1 270 000
Comprehensive Coal Preparation Plant Performance Evaluation	-	-	-	-	46 943	81 000	127 943
transCOM Co-ordinated Vendor Test	-	-	296 623	51 452	-	-	348 075
Feasibility Study - IGCC Power Plant	-	-	-	124 167	-	-	124 167
TOTAL: WESTERN CANADIAN LOW-SULPHUR COAL TO ONTARIO PROGRAM	0	363 039	2 238 432	603 225	709 894	1 045 000	4 959 590
TOTAL: COAL RESEARCH PROGRAMS	34 881 011	4 471 701	6 625 896	3 117 977	2 023 291	1 270 732	52 390 608
PROGRAM ADMINISTRATION	-	-	90 699	105 409	215 118	131 242	542 468

Figure 1: Research Expenditure on Approved Projects (excluding Coal Research Centre, Devon)

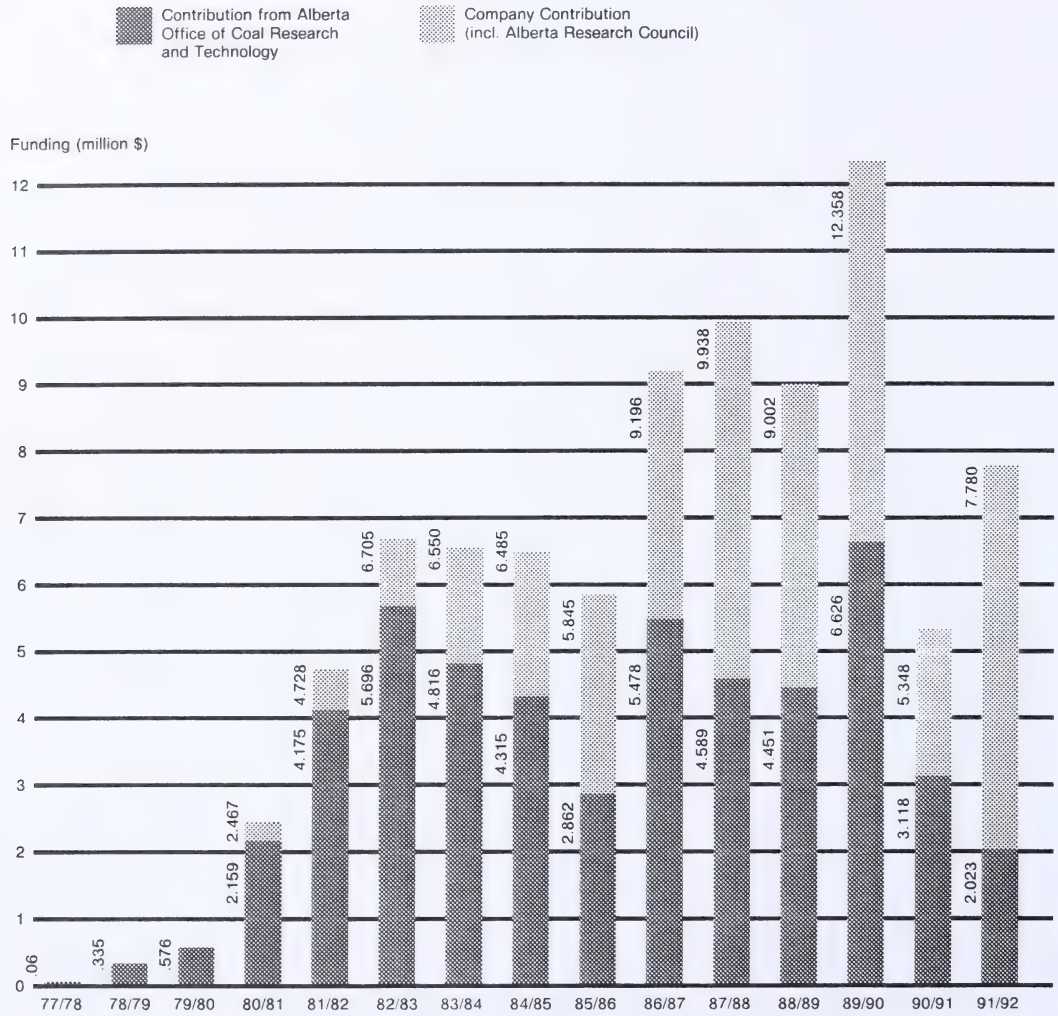
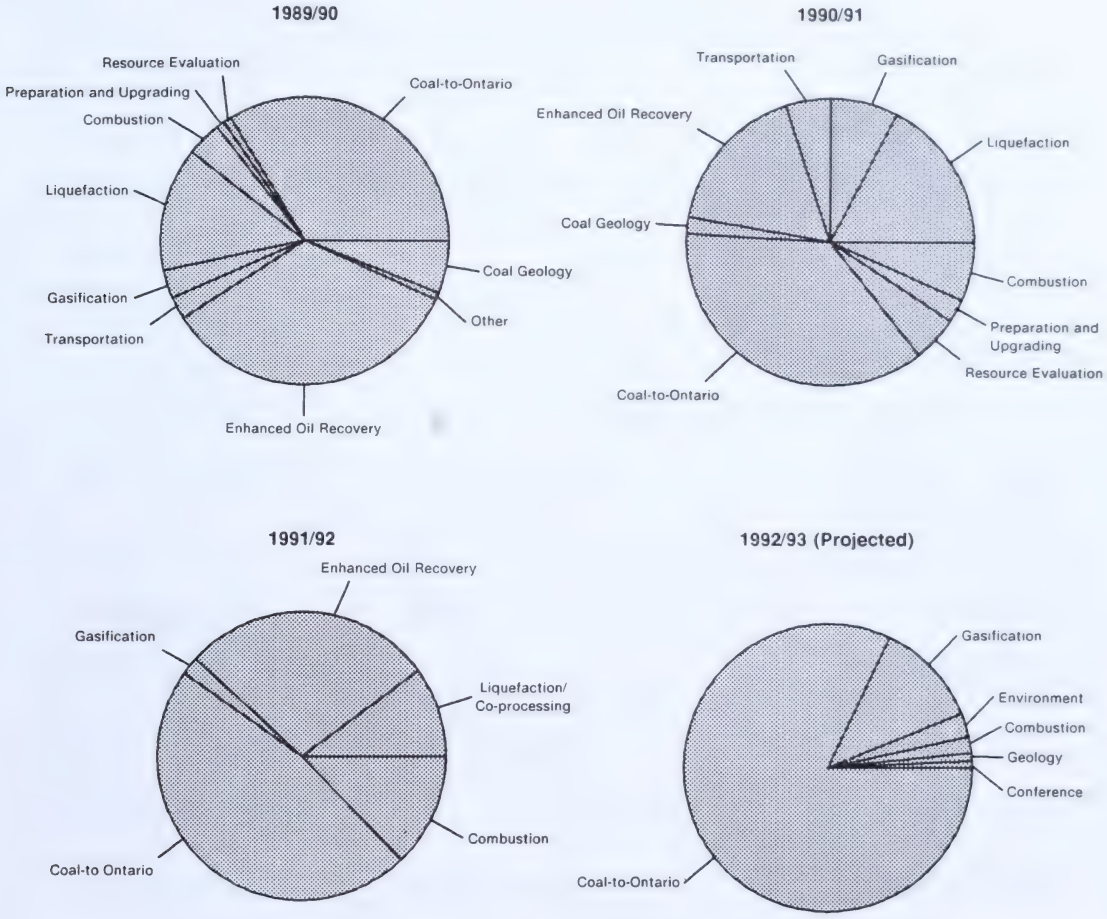


Figure 2: Distribution of Alberta Office of Coal Research and Technology Funding Contributions



Appendix

Projects Supported by the Alberta Office of Coal Research and Technology and Their Status

A/CERRF-Funded Projects

Project	*Researcher*	*Status*
Resource Evaluation		
Analysis of Coal-Bearing Strata Near Cadomin	H.A.K. Charlesworth, University of Alberta	Completed in 1981/82
Creep Characteristics of Coal	D.M. Cruden, University of Alberta	Completed in 1984/85
Reflective Seismic Investigation of Western Canadian Coalfields	D.C. Lawton, The University of Calgary	Completed in 1984/85
Very Low Frequency Geophysical Methods in Coal Exploration	Smoky River Coal Limited	Completed in 1985/86
Potential of Geophysical Techniques for Coal Exploration	Coal Mining Research Company	Completed in 1985/86
Geotechnical Properties of Overburden	Coal Mining Research Company	Completed in 1985/86
Surface Geophysical Coal Exploration	TransAlta Utilities Corporation and Others	Completed in 1986/87
Structural Geometry of Imbricated Thrust Sheets	D.A. Spratt, The University of Calgary	Completed in 1986/87
In-Seam Coal Characterization	Coal Mining Research Company	Completed in 1987/88
Seismic Modelling of Shallow Coalfields	D.C. Lawton, The University of Calgary	Completed in 1989/90
Downhole Geophysics	TransAlta Utilities Corporation and Others	Completed in 1990/91
Surface Geophysical Techniques for Foothills and Mountain Coalfield Exploration	Esso Resources Canada Limited and Others	Completed in 1990/91
Coal-Bed Methane: An Alberta Opportunity[1]	Alberta Research Council	Completed in 1991/92

[1]Supported by the Department of Energy in 1991/92.

Project	*Researcher*	*Status*
Mining		
Support Design for Underground Cavities in Weak Rock	N.R. Morgenstern, University of Alberta	Completed in 1978/79
Coal Mining Research	Coal Mining Research Company	Completed in 1985/86
Coal Mining in 2035	Coal Mining Research Company	Completed in 1985/86
Triaxial Test Development	Coal Mining Research Company	Completed in 1986/87
Ground Movements in Coal Mines	D.M. Cruden, University of Alberta	Completed in 1986/87
Mining 2035 Workshop	Coal Mining Research Company	Completed in 1986/87
Robotics for Mine Control	Coal Mining Research Company	Completed in 1986/87
Non-Cable Vehicle Guidance	Coal Mining Research Company	Completed in 1987/88
Lasers in Coal Mining	Coal Mining Research Company	Completed in 1987/88
Geostatistics	Coal Mining Research Company	Completed in 1987/88
Footwall Anchoring	Smoky River Coal Limited	Completed in 1987/88
Time-Dependent Behaviour of Coal Measure Rocks	R. Day, The University of Calgary	Completed in 1988/89
Deformation and Progressive Failure of Open-Pit Highwalls	N.R. Morgenstern, University of Alberta	Completed in 1988/89
Automated Machine Control for Optimized Mining (AMCOM)	Coal Mining Research Company	Completed in 1988/89
Dragline Operations Monitor	Coal Mining Research Company	Completed in 1988/89
Preparation and Upgrading		
Coal Ash Monitoring System	L.R. Plitt, University of Alberta	Completed in 1982/83
Mathematical Modelling of Automedium Cyclones	L.R. Plitt, University of Alberta	Completed in 1984/85
Beneficiation of Coal by Agglomeration in Pipelines	Alberta Research Council/ University of Alberta	Completed in 1984/85
Coal Preparation Research	Coal Mining Research Company	Completed in 1985/86

Project	*Researcher*	*Status*
Coal Comminution	Coal Mining Research Company	Completed in 1986/87
Numerical Analysis of Process Yield Losses	Coal Mining Research Company	Completed in 1986/87
Advanced Processes for Low-Rank Coal	Coal Mining Research Company	Completed in 1986/87
Properties of Thermally Dried Coals	Coal Mining Research Company	Completed in 1986/87
Stabilization of Dried Coal	Coal Mining Research Company	Completed in 1986/87
Agglomeration of Low-Rank Alberta Thermal Coals	Alberta Research Council	Completed in 1986/87
Agglomeration for Beneficiation	Manalta Coal Limited	Completed in 1986/87
Preparation and Upgrading Assistance	Coal Mining Research Company	Completed in 1987/88
Moisture and Ash On-Stream Analyser	Coal Mining Research Company	Completed in 1987/88
Recovery of Coal from Tailings	Coal Mining Research Company	Completed in 1987/88
Fine Coal Technical Assistance	Coal Mining Research Company	Completed in 1987/88
Froth Flotation Study at Coal Valley	Luscar Sterco (1977) Ltd.	Completed in 1987/88
Washery Optimization	Coal Mining Research Company	Completed in 1988/89
Coal Beneficiation Process	Gulf Canada Resources Limited and Unocal Canada Limited	Completed in 1988/89
Agglomeration of Coking Coal	Smoky River Coal Limited	Completed in 1988/89
WESTCOAL Separator	Coal Mining Research Company	Completed in 1989/90
Coal Production Program Planning	Coal Mining Research Company	Completed in 1989/90
Coal Agglomeration Process Development	Alberta Research Council	Completed in 1990/91
Particle Distribution in Slurry Flow Through Tees and Manifolds	J.H. Masliyah, University of Alberta	Completed in 1990/91
Electrocoagulation	Luscar Sterco (1977) Ltd. and Others	Completed in 1991/92
Coal/Oil Upgrader	Fording Coal Limited and Others	Completed in 1991/92

Project	*Researcher*	*Status*
Combustion		
Smoky DENSECOAL Combustion Tests	Monenco Consultants Ltd.	Completed in 1985/86
Combustion of Agglomerated Coal	Luscar Ltd.	Completed in 1985/86
Combustion Process Research	Alberta Research Council	Completed in 1986/87
Combustion Characteristics of Alberta Coals	Alberta Research Council	Completed in 1986/87
Combustibility of Agglomerates	Alberta Research Council	Completed in 1986/87
Combustion Program Planning	Alberta Research Council	Completed in 1987/88
Influence of Porosity on Combustion	Alberta Research Council	Completed in 1987/88
Causes of Spontaneous Combustion of Western Canadian Coals	F.W. Bachelor, The University of Calgary	Completed in 1987/88
Combustibility of Upgraded Alberta Coals	Alberta Research Council	Completed in 1987/88
Evaluation of Blending on Combustibility	Alberta Research Council	Completed in 1987/88
Prediction of Coal Combustibility	Esso Resources Canada Limited	Completed in 1987/88
Combustion Properties of Alberta Coals and Chars	Alberta Research Council	Completed in 1988/89
Spontaneous Combustion of Thermally Treated Coals	Unocal Canada Limited and Others	Completed in 1988/89
International Energy Agency Basic Coal Combustion Science	Netherlands Energy Research Foundation ECN	Completed in 1988/89
A Thermodynamic Model for the Spontaneous Combustion of Coal	R. Paul, The University of Calgary	Completed in 1989/90
Sources of Ash Under Controlled Conditions	R.C. Joshi, The University of Calgary	Completed in 1989/90
Ash Properties of Alberta Coals	Alberta Research Council	Completed in 1991/92
International Energy Agency Basic Coal Combustion Science - Program Extension	Netherlands Energy Research Foundation ECN	Continuing
Coal Utilization Program Planning (renamed Technology Transfer of IEA Coal Combustion Sciences Research)	Alberta Research Council	Continuing

Project	*Researcher*	*Status*
Liquefaction/Co-processing		
Coal Liquefaction Study	Kilborn Alberta Limited	Completed in 1981/82
Coal Liquefaction Feasibility Study	Contar Systems Engineering Ltd. and Others	Completed in 1984/85
Synthetic Fuels Program	SRI International	Completed in 1984/85
Economic Evaluation of Coal/Oil Co-processing	HRI Inc	Completed in 1984/85
PYROSOL Process Review	Canadian Utilities Ltd. and Luscar Ltd.	Completed in 1985/86
Liquefaction Process Improvements	Alberta Research Council	Completed in 1985/86
Hydroprocessing of Coal-Based Liquids	I.G. Dalla Lana, University of Alberta	Completed in 1985/86
Supercritical Gas Extraction of Coal	N. Berkowitz, University of Alberta	Completed in 1985/86
ENR/ARC Coal Conversion Research	Alberta Research Council	Completed in 1986/87
New Liquefaction Processes	Alberta Research Council	Completed in 1986/87
Liquefaction Process Evaluation	Alberta Research Council	Completed in 1986/87
Isotopic Analysis of Co-processing Schemes	K. Muehlenbachs, University of Alberta	Completed in 1986/87
Secondary Upgrading	Alberta Research Council	Completed in 1987/88
Functional Group Analysis of Coal Liquids	M.R. Gray, University of Alberta	Completed in 1987/88
Chemistry of Coal Liquefaction	Alberta Research Council	Completed in 1988/89
Secondary Upgrading of Co-processing Products	Alberta Research Council	Completed in 1988/89
Supercritical Gas Extraction of Coal	N. Berkowitz, University of Alberta	Completed in 1988/89
Liquefaction of Coal with Natural Gas	M.R. Gray, University of Alberta	Completed in 1988/89
Hydroprocessing of Coal-Derived Liquids	I.G. Dalla Lana, University of Alberta	Completed in 1988/89

Project	*Researcher*	*Status*
Isotopic Studies of Coal/Bitumen Co-processing Schemes	K. Muehlenbachs, University of Alberta	Completed in 1989/90
Molecular Interactions Between Heavy Oil and Coal Species During Co-processing	P.D. Clark, The University of Calgary	Completed in 1989/90
Product and Process Characterization	Alberta Research Council	Completed in 1990/91
Co-processing Process Development	Canadian Energy Developments Inc.	Completed in 1990/91
Co-processing of Coal with Molten Halide Catalysts	A. Chakma, The University of Calgary	Completed in 1991/92
Combined Processing of Coal, Heavy Oil and Natural Gas	M.R. Gray, University of Alberta	Completed in 1991/92
Specialty Chemicals from Coal-Derived Liquids	Alberta Research Council	Completed in 1991/92
Coal/Oil Co-processing Using a Counterflow Reactor	Canadian Energy Developments Inc.	Completed in 1991/92
Co-processing of Coal and Heavy Oil in Alberta, Phase II	Alberta Oil Sands Technology and Research Authority	Continuing

Gasification

Gasification of Western Canadian Coals	TransAlta Utilities Corporation and Others	Completed in 1986/87
Fluidized Bed Gasification of Highvale Coal	TransAlta Utilities Corporation and Others	Completed in 1987/88
Economics of Coal Gasification	Alberta Power Limited and Others	Completed in 1987/88
Gasification Process Research	Alberta Research Council	Completed in 1987/88
Gasification Properties of Alberta Coals	Alberta Research Council	Completed in 1987/88
Gasification Laboratory Facilities	Alberta Research Council	Completed in 1987/88
Corrosion in Gasification Systems	W.J.D. Shaw, The University of Calgary	Completed in 1987/88
Gasification Characteristics of Alberta Coals	Alberta Research Council	Completed in 1988/89

Project	*Researcher*	*Status*
Devolatilization Properties of Alberta Coals	Alberta Research Council	Completed in 1988/89
IGCC Utility Applications	TransAlta Utilities Corporation and Others	Completed in 1989/90
Gasification Properties of Alberta Coals	Alberta Research Council	Completed in 1991/92
Canada/Japan Collaboration on Coal Gasification Research	Alberta Research Council	Continuing

Transportation

Coal Slurry Pipeline Research	Pembina Resources Ltd.	Completed in 1984/85
Coal/Oil/Natural Gas Transportation System	CERI Energy Research Ltd.	Completed in 1987/88
Coal Market Access Model	Trimac Consulting Services Ltd.	Completed in 1988/89
Coal-Oil Slurry Pipelining	Unocal Canada Limited	Completed in 1988/89
Coal Slurry Technology	Salzgitter Industriebau GmbH and Others	Completed in 1990/91

Environment

Coal Conversion Waste-Water Treatment	S.E. Hrudey, University of Alberta	Completed in 1984/85
Low NO_x/SO_x Burner	TransAlta Utilities Corporation	Completed in 1986/87
Coal Conversion Waste-Water Treatment	S.E. Hrudey, University of Alberta	Completed in 1987/88
Sorbent Injection Study	Alberta Power Limited and Others	Completed in 1988/89
A Review of Carbon Dioxide Separation, Disposal and Utilization Technologies	TransAlta Utilities Corporation and Others	Completed in 1990/91
Use of Gypsum as Flocculent for Treatment of Mine Effluent Waters	TransAlta Utilities Corporation	Completed in 1991/92

Project	*Researcher*	*Status*
Markets		
Conversion from Oil to Coal-Water Fuels	Smoky River Coal Limited	Completed in 1985/86
Production of Activated Carbon	E.L. Tollefson, The University of Calgary	Completed in 1985/86
Activated Carbon from Coal	E.L. Tollefson, The University of Calgary	Completed in 1987/88
Enhanced Oil Recovery		
Fuel Options for Enhanced Oil Recovery	L.A. Smith Consulting and Development Ltd.	Completed in 1985/86
Coal Use in Enhanced Oil Recovery	Luscar Ltd. and Others	Completed in 1987/88
Coal-Fired Steam Injection Boiler	Fording Coal Limited and Others	Completed in 1988/89
Application of the LNS Burner to an Oil Field Steam Generator	TransAlta Resources Investment Corporation and Others	Completed in 1988/89
Economics of Coal Use for Heavy Oil Recovery	Shell Canada Limited	Completed in 1989/90
Coal-Condensate Slurry Pipelining	Unocal Canada Limited	Completed in 1990/91
Coal-Condensate Slurry Pipelining - Engineering/Cost Study	Unocal Canada Limited	Completed in 1990/91
LNS Burner Steam Generator Demonstration	TransAlta Resources Investment Corporation and Esso Resources Canada Limited	Completed in 1991/92

Project	*Researcher*	*Status*
Other		
Coal Technology Information Centre	Alberta Research Council	Completed in 1985/86
Technical Information Needs	Crozier Information Resources Consulting Ltd.	Completed in 1985/86
Data Gathering for Research Planning	Coal Mining Research Company	Completed in 1986/87
Electrolysis of Coal Slurries	V.I. Birss, The University of Calgary	Completed in 1986/87
Sulphur Isotope Studies of Coal	R.H. Krouse, The University of Calgary	Completed in 1988/89
Electrolysis of Coal Slurries in New Environments	V.I. Birss, The University of Calgary	Completed in 1988/89
Distributed Chemical and Physical Properties of Coal	P.J. Crickmore, University of Alberta	Completed in 1988/89
Magnetic and Electric Properties of Alberta Coals	H.A. Buckmaster, The University of Calgary	Completed in 1989/90
Distribution of Oxygen Forms in Western Canadian Low-Rank Coals	N. Berkowitz, University of Alberta	Completed in 1989/90

Department-Funded Projects

Synthetic Fuels Program	SRI International	Completed in 1984/85
Economic Evaluation of Coal/Oil Co-processing	HRI Inc.	Completed in 1984/85
Smoky DENSECOAL Combustion Tests	Monenco Consultants Ltd.	Completed in 1985/86
Economics of Coal Gasification	Alberta Power Limited and Others	Completed in 1987/88
Corrosion in Gasification Systems	W.J.D. Shaw, The University of Calgary	Completed in 1987/88
Coal/Oil/Natural Gas Transportation System	CERI Energy Research Ltd.	Completed in 1987/88

Project	*Researcher*	*Status*
Coal for Use in Enhanced Oil Recovery: Emission Control Technology	Esso Resources Canada Limited and Others	Completed in 1987/88
Alberta Coal Geology Project	Alberta Research Council	Completed in 1989/90
Counterflow Reactor Development, Phase II	Canadian Energy Developments Inc.	Completed in 1991/92
Coal Research Contractors' Conference	Info-Tech Conference Management	Completed in 1991/92
CO_2 Disposal/Utilization Workshop	Info-Tech Conference Management	Completed in 1991/92
Process Development for Carbon Fibre from Coal-Derived Liquid	Alberta Research Council	Continuing
Impact of Quality on the Utilization Potential of Alberta Coals and Its Effect on the Environment	Alberta Research Council	Continuing
Canadian Coal Gasification Project	Alberta Research Council/CANMET	Continuing
Development of Sport Fisheries in Lakes Created by Coalmining Operations in the Eastern Slopes	Luscar Sterco (1977) Ltd.	Continuing
CO_2 Disposal Study - Phase II	AOSTRA	Continuing
Greenhouse Gases R&D Program	International Energy Agency	Continuing

Western Canadian Low-Sulphur Coal to Ontario Program

HYDROSIZER for Fine Coal Recovery from Tailings	Obed Mountain Coal Company Limited	Completed in 1989/90
Testing of ARCOFLUX 130	Obed Mountain Coal Company Limited	Completed in 1989/90
transCOM Coordinated Vendor Tests	Unocal Canada Limited	Completed in 1989/90
Thermal Drying of Western Canadian Low-Rank Coals	TransAlta Utilities Corporation	Completed in 1990/91
Developing a Practical Model for the Compound Water Cyclone	Cyclone Engineering Sales Ltd.	Terminated in 1990/91

Project	*Researcher*	*Status*
On-Line Coal Analysers	RadioMetrics Engineering Ltd.	Terminated in 1990/91
Feasibility Study - IGCC Power Plant	The Coal Association of Canada	Completed in 1991/92
Thick-Seam Extraction and Continuous Haulage Mining Demonstration	Smoky River Holdings Ltd.	Completed in 1991/92
Air-Sparged Hydrocyclone	Hydro Processing & Mining Ltd.	Completed in 1991/92
Tailings Reclamation	Luscar Sterco (1977) Ltd.	Continuing
Coal/Oil Upgrader - Phase II	Fording Coal Limited and Others	Continuing
Comprehensive Coal Preparation Plant Performance Evaluations	The Coal Association of Canada	Continuing

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